MEDICAL DEPARTMENT

FIELD RESEARCH LABORATORY

Fort Knox, Kentucky

ANNUAL HISTORICAL REPORT

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MEDICAL DEPARTMENT FIELD RESEARCH LABORATORY

Fort Knox, Kentucky

MEDEA

SUBJECT: Annual Historical Report, 1948

TO: The Surgeon General
U. S. Army
Washington 25, D. C.

1. The following Annual Historical Report for the calendar year 1948 is submitted for your information.

2. Introduction (historical Background)

The Armored Medical Research Laboratory was established at Fort Knox, Kentucky, on 1 September 1942.

The Laboratory was operated under the supervision and control of the Commanding General, Army Ground Forces, from 1 September 1942 until 3 February 1944, at which time control and supervision was transferred to the Office of The Surgeon General and the Laboratory designated as a Class IV installation.

Effective 1 April 1947, the Armored Medical Research Laboratory was redesignated as The Medical Department Field Research Laboratory by War Department General Order No. 32, dated 19 March 1947.

3. Function

Under the general supervision of the Army Medical Research and Development Board of the Office of The Surgeon General, U. S. Army, to conduct research on various physiological and closely related aspects dealing with the inter-relationship between man and his equipment and supplies, disease, his environment and the military tasks assigned to him with the objective of constant improvement.

4. Organization

The Medical Department Field Research Laboratory is now composed of three branches and nine sections as follows:

a. Administrative Branch
   - Medical Supply Section
   - Medical Detachment
   - Utilities and Maintenance
   - Research Library

b. *Research Branch*
   X-Ray and Photographic Section
   Biophysics Section
   Physiology Section
   Biochemistry Section
   Field Test Section

c. Psychology Branch

Authorized strengths:

Military	Authorized	Assigned
Officers -	22	20
Enlisted -	23	23
Civilians -	67	60
TOTAL	112	103

Authorization of Graded Civilians:

Total Graded	Group A	Group B	Group C	Group D
46	0	12	6	28

5. Physical Plant

19 Buildings

1 Permanent Building (Main Laboratory)
18 Frame Buildings
   1 Chemistry Laboratory
   1 CNS Physiology Laboratory
   1 Biophysics Laboratory
   1 X-Ray and Photographic Laboratory
   1 Hematology Laboratory
   2 Psychology Laboratories
   1 Barracks, Enlisted
   1 Animal House
   1 Carpenter Shop
   1 Paint Shop
   1 Machine Shop
   2 Supply Buildings
   4 Storage Buildings

6. Accomplishments

During the year, seven projects were completed (see Appendix A) and three articles appeared in various journals (see Appendix B). With the exception of the Psychology Branch, all civilian positions were

filled during the year.

The conversion of frame buildings into laboratories has proved a very satisfactory substitute for permanent buildings, because each laboratory could be designed to accomplish its particular mission without excessive cost.

At the end of the year, nineteen (19) projects were underway (see Appendix C).

It is now believed that the research program is on a sound basis and that more and more work will appear in the future. The reorganization period is more or less over and the laboratory has survived its "growing pains". The staff is well balanced and of high caliber, and forms the nucleus of a small, but excellent medical research group.

During the year, recognition of the caliber of the staff was evidenced by the great increase in the number of requests for consultations and advice from higher headquarters, other laboratories, etc. A number of the senior staff members have been appointed to positions on various panels for the Military Establishment.

Excellent liaison has been established with the British and Canadians so that there is a ready exchange of information. The same is true with other branches of the National Military Establishment.

It is believed that duplication and overlapping of scientific effort has been cut to a minimum consistent with good scientific investigation.

F. J. Knoblauch
F. J. KNOBLAUCH
Lt. Colonel, MC
Commanding

COMPLETED PROJECT REPORTS

PROJECTS COMPLETED IN 194[illegible]

1. Observations with Army Ground Forces Task Force Frigid and Williwaw. Molnar, Magee and Durrum.

2. Observations on Physiological Problems in Desert Heat - Task Force Furnace, Yuma, Arizona. Clarke and Talso.

3. Laboratory Photoplanator. Carpenter

4. Effects of Atropine and Pilocarpine on Human Thermoregulation. Palmes, et al.

5. An Analysis of Cerebral Control of Reflex Pupillary Dilatation in the Cat. Wilson.

6. The Regulation of Body Temperature During Fever. Park and Palmes.

7. Some Preliminary Observations on the Effects of Ultraviolet Light, Alpha Rays and X-Rays on 2, 3, 5 Triphenyltetrazolium Chloride Solutions. Gierlach and Krebs.

No. 1

OBSERVATIONS WITH

AGF TASK FORCES FRIGID AND WILLIWAW

by

G. W. Molnar, Physiologist, R. B. Magee, Capt., M.C.
and E. L. Durrum, Capt., M.C.

from

Medical Department Field Research Laboratory
Fort Knox, Kentucky

12 January 1948

*Sub-project under Cold, Study of Physiological Effects of.
Approved 25 September 1942. MDFRL Project No. 6-64-12-02-(2).

Project No. B-6-64-12-02
Sub-project MDFRL 02-2
MEDEA

12 January 1948

ABSTRACT

OBSERVATIONS WITH AGF TASK FORCES FRIGID AND WILLIWAW

OBJECT

During the winter of 1946-1947 three observers from this laboratory conducted physiological observations on troops in the field at Task Force Frigid and Task Force Williwaw, and also on Eskimos at Barrow, Alaska. To enhance the value of cursory visual impressions, special tests under controlled conditions were performed. Information was obtained concerning problems of water balance and endurance, and also concerning the body temperature responses of Eskimos as compared with those of white men.

RESULTS

1. Pure-breed Eskimos maintained warmer finger temperatures than white men during the first 1 to 3 hours of exposure to outdoor weather under identical conditions. These results suggest values to look for in the preselection of men for arctic duty and in the assessment of acclimatization changes.

2. Twelve men in the field for 4 to 5 days maintained water balance at both Task Force Frigid and Task Force Williwaw, although water was available only from E rations and natural sources. In neither case, however, was the weather too severe or the equipment inadequate for the procurement of water. In some instances the urinary concentration of solids approached limiting values although the urinary volumes were moderately high. The potential importance of the water-balance problem is emphasized.

3. Measurements of blood and plasma specific gravities, hemoglobin concentration and hematocrit ratio were within normal ranges and did not show any hemoconcentration as a result of a winter's residence in the Arctic at Task Force Frigid.

4. Five of 9 men at Task Force Williwaw found conditions in a foxhole test unendurable for more than 16 hours, despite the fact that they showed no physiological responses significantly different from those of the 4 men who could have carried on longer. Psychophysiological factors seemed to limit endurance, as indicated by inhibition of hunger, tendency to feel cold and to become angry, and the tendency to sit and shiver rather than to move around to keep warm.

CONCLUSIONS

Cold can limit performance and endurance not only directly, but also indirectly, by causing other factors to become stresses. Dehydration, reduction of food intake, shivering, inability to sleep, extra work necessary to

perform a task, all caused by the cold environment, can lead to reduced efficiency and exhaustion even though the body has suffered no significant temperature drop or decrement in dexterity. Minor stimuli, e.g., wetness, reduced digital temperatures, uncomfortable posture, etc., can summate over a period of time to elicit psychophysiological reactions and subjective distresses which limit endurance. These induced stresses and additive stimuli will or will not make their appearance depending upon not only meteorological phenomena, but also the available equipment and facilities, available time, terrain, training, duration of field exercise, psychological characteristics of the individual and the group, etc. Because so many complicated factors are involved, it is hazardous to make generalized predictions or statements of any kind on the basis of temperature and wind alone.

There is little scientific information concerning such problems as preselection, acclimatization, endurance, survival, etc., as influenced by hypothermia. Empirical statements usually resolve themselves into personal bias based upon incomplete observations and personality factors. Exaggeration of conditions and accomplishments is often employed.

RECOMMENDATIONS

Although many problems can be studied only in the field, emphasis at this time should be placed upon laboratory development of techniques and concepts and accumulation of fundamental data. Many small field projects concerning physiological reactions to cold can be performed as well or better in the cold room as in the far North.

Submitted by:
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Commanding

OBSERVATIONS WITH
AGF TASK FORCES FRIGID AND WILLIWAW

INTRODUCTION

In July 1946 the Medical Department Field Research Laboratory was invited by the Army Ground Forces to send observers to Task Forces Frigid and Williwaw. The party selected consisted of one civilian scientist and two medical officers. The general objectives were to make general observations on the reaction of man to the environment and to obtain what data that could be acquired under the particular field conditions. Specifically the objectives were:

1. To ascertain the problems concerning the reactions of men in wet and dry-cold environments;

2. To describe the factors which limit performance and survival in these environments;

3. To acquire personal, first-hand experience of living in these environments.

It was decided that, since observers from other units of the Army would be concerned with problems of clothing and shelter, nutrition, sanitation, and general medical procedures, the party from this laboratory would direct its attention primarily to the physiological aspects of activities in the north country. Further thought on the matter led to the following conclusions:

1. That simple visual observation of men would yield only a very limited amount of information about physiology;

2. That measurements would have to be made to substantiate superficial impressions;

3. That measurements necessitate the use of instruments, which would have to be transported;

4. That measurements are usually meaningless, if there is no control over the situation.

For these reasons it was decided to collect the necessary instruments and to submit a request for 10 subjects, either to be taken along or to be furnished by the Task Forces. Great difficulty was experienced in procuring even the minimum of apparatus on short notice, and the request for test subjects was rejected because the Task Forces were limited both in manpower and in accommodations.

At this juncture the observers decided to run some tests on themselves in the cold room of the laboratory to see if it would be feasible to conduct similar observations on themselves in the field. These tests, in addition, served to accustom the observers to operating in the cold in heavy clothing, and to obtain basic data on themselves. It was soon learned, however, that three men would find it tremendously difficult to act as both test subjects

and observers, and the prospect for making systematic measurements in the field seemed extremely remote. Nevertheless, preparations were continued in the hope that the Task Forces would find it possible to assign some men for certain tests.

As it turned out, both Task Forces very generously assigned test subjects. In addition, it was possible to conduct observations on Eskimos during the Christmas recess. Before describing these studies, however, the itinerary will be outlined briefly.

ITINERARY AND PROGRAM

Although arriving at different times, all the observers were signed in at Task Force Frigid on 2 December 1946. The thermocouple equipment however, was not delivered until 7 December, and the rest of the scientific apparatus shipped from Fort Knox did not arrive until after the observers had left for Barrow, Alaska.

December 2 to 22: The facilities for investigation available during this time were mainly those provided by the Medical Detachment, viz., a laboratory room with tables, sink with running hot and cold water, and a centrifuge. The thermocouple apparatus required repair of breakage sustained during transport from Fort Knox before it could be used. The repairs were completed just before the party left for Barrow.

The principal observations made during this period were cursory ones of men in quarters and in the field. The work of the ice-bridge crew, firing on the rifle range, the construction of the AAA tower, repair of vehicles, tank driving, etc., were observed. The field exercises planned by the Task Force for December were postponed because of the difficulties in constructing the ice-bridge, which was necessary for transporting heavy equipment to firing territory across the Tanana River.

In addition to the above activities, the observers also conferred with the Cold Weather Test Detachment at Ladd Field with respect to evacuation by helicopter and by glider. Considerable time was also put into preparation for the Eskimo studies.

December 22, 1946 to January 8, 1947: Investigations were conducted on the Barrow Eskimos as to their temperature responses to cold weather.

January 8 to 11: Preparations were made for the trip to Task Force Williwaw, both on a mountain maneuver and in foxholes.

January 11 to 30: Tests were conducted on 10 subjects on Task Force Williwaw, both on a mountain maneuver and in foxholes.

January 30 to February 9: The observers were detained at Anchorage on the return trip from Adak, because no planes were flying to Ladd Field due to the low temperature. The interval was utilized in preparing a preliminary report for Task Force Williwaw on the studies conducted on Adak.

February 9 to 26: Following the return to Task Force Frigid, only a limited amount of activity could be pursued because two of the observers were afflicted with acute upper respiratory infection. The preliminary report to

Task Force Williwaw was completed and copies were forwarded to that force. In addition, preparations were made for field testing on men.

February 26 to March 4: Water-balance tests were conducted at Task Force Frigid on 10 subjects while living in bivouac. Additional tests planned for the subsequent five days could not be carried through due to the breakdown of the thermocouple potentiometer. The whole test program, therefore, was terminated on March 4 and the observers returned to Fort Knox. Before leaving they submitted a memorandum report on their activities to the Task Force officers.

RESULTS OF SPECIAL TESTS

The fundamental objective of all the tests was to obtain a description in quantitative terms of the physiological reactions of men while in the line of duty in the field. The nature of the control exercised in the field will be explained for each test separately. Special laboratory-type experiments were deemed out of place, except as they might prove worthwhile to check some observation made in the field. It was considered that the outdoors should be utilized, not as a laboratory room, but as an environment which could not be successfully duplicated indoors.

Despite the fact that much time has already been spent in analyzing the data, most of the conclusions in this report are to be considered tentative. Several of the individual problems will be tested by further experiments at Fort Knox and detailed reports will be submitted at a later date.

TEMPERATURE RESPONSES OF ESKIMOS TO OUTDOOR WEATHER

(With the collaboration of Major Harold L. Freitman, SnC., and Lt. William C. Harstad, DC., USNR.)

I. INTRODUCTION

Physiological investigations on natives who endured the cold with great hardihood, are of value to the Army in that they may disclose physiological mechanisms which adapt a man to the Arctic. This knowledge could then be used, both in the preselection of men for arctic duty, and in assessing the adaptive value of any acclimatization changes that may be found to occur in white men following prolonged or repeated exposure to the cold.

The only available scientific studies relative to body temperature of natives in the cold are those of Hicks and O'Connor (1938) on the naked Australian aborigines. They found that when naked black and white subjects were cooled under identical atmospheric conditions, their skin temperatures fell to the same extent. Furthermore, these workers stated that the radial artery constricted in the natives after less cooling than in the whites. The natives apparently experienced as keenly as the whites the subjective sensations of cold when awake, but not when asleep (Goldby et al, 1938).

Despite these findings, the possibility still exists that the Eskimos may possess thermal responses different from those of white men. The basal metabolism of the Australian natives is apparently -12% to -30% (Wardlaw and Horsley, 1928; Wardlaw and Lawrence, 1932; Hicks et al, 1931, 1933, 1934). The basal metabolism of Eskimos, on the other hand, is +13% to +33% (Crile and Quiring, 1939; Heinbecker, 1928; Rabinowitch and Smith, 1936). (In another study in which the protein intake was reduced to half that in the first investigation, Heinbecker (1931) found that the basal metabolisms of his 4 Eskimo subjects were the same as the DuBois normal standards). If the basal metabolism of the Eskimo is really higher than the average basal metabolism of the white man, then the Eskimo could also be expected to sleep or rest quietly in the cold with greater comfort than white men. Heinbecker, (1932) also found that the fasting Eskimo does not exhibit the ketogenesis normally found among white men. If fat combustion is complete in the Eskimo, then the small Eskimo could compete with the large white man in combating the cold by a more effective utilization of stored energy. Obviously, the value of metabolic and biochemical studies on the Eskimo would be enhanced, if it could be shown that he also maintains body temperatures which adapt him to the cold better than the temperatures of white men do.

The opportunity to study the temperature responses of Eskimos presented itself when the troops were given Christmas leave. The commanding officer of Task Force Frigid arranged with the Navy to have the tests performed on the Barrow Eskimos. It had not occurred to the observers that these Eskimos might also be celebrating the Christmas season. Actually, they had a well organized program lasting over a week and the festivities considerably reduced the time available for test purposes. In fact, most of the tests had

to be run in the evening and had to be fitted into the general schedule when they would least interfere with the events of the week.

It is necessary to note briefly a few observations which have a bearing on the value of using the Barrow Eskimos as subjects for this investigation. It is often said that the white man has caused a negative alteration in both the genetics and living habits of the Alaskan Eskimos. Even before the appearance of the white man, however, the Eskimo population of North America was probably not genetically homogenous (Shapiro, 1931). Hawkes (1916) found the Alaskan Eskimos to be larger and more robust than those of Eastern Canada. The admixture of white blood in the Eskimos of this study, as ascertained both by interrogation and by examination of the records of the U. S. Commissioner, is noted below. The present inhabitants of Barrow are recent immigrants (or their descendants) from places as far apart as St. Lawrence Island in the Bering Sea and the mouth of the Mackenzie River (Stefansson, 1938). In 1908, Stefansson found that no more than 7 per cent of the Barrow population belonged to the earlier tribe, which had died out. (At present there is no village at Point Barrow, which is about 14 miles northeast of Barrow.) The newcomers to Barrow adopted the white man's dwellings and other habits, and abandoned many of the former ways of living (described by Murdock, 1887). The houses which the observers visited were well-built frame structures heated by coal stoves; the measured temperatures 3 feet above the floor were about 72°F. Although living as white men do in their houses, the Barrow Eskimos still depend largely upon hunting and maintenance of a reindeer herd for their food supply, although a cash income may be obtained from the sale of pelts and ivory, and from employment by the Government. The population is still ravaged by tuberculosis, but Dr. E. S. Rabeau, of the government hospital there, did not believe that the Eskimos who acted as test subjects were afflicted by the disease.

II. EXPERIMENTAL

A. Design of the Tests

1. Basic Plan.

a. To make valid comparisons between Eskimos and white men it was necessary that they be exposed under as nearly identical conditions as possible. This meant that the following conditions had to be fulfilled:

(1) Weather conditions had to be the same. Inasmuch as the exposures were to be in the uncontrollable weather of the outdoors, one white man was to be with the Eskimos in each test. (The paucity of white subjects made it impossible to have more than one in a test.)

(2) Clothing had to be the same for all men. Hence, army uniforms were taken up from Task Force Frigid to clothe the Eskimos.

(3) Activity had to be the same. It was desired that two extremes of activity be utilized--quiet sitting and brisk walking. Only the sitting tests, however, were performed. Shivering was not considered as activity, but as an adaptive response to the cold.

(4) The physiological state should be the same. Because the Eskimos both worked and attended their festivities, it was out of the question to try to exercise any control over eating, sleeping, and exhaustive work prior to the test. All that could be done was to take the men as they presented themselves and enter a few notations about their preceding activities. In addition, a simple cardiovascular test was performed just before each exposure to get some index of the physiological state.

b. In case the Eskimos in army clothing showed no temperature responses different from those of the white men, it was planned to have in each test one Eskimo in his own fur clothing, to see if it is their clothing which enables them to stay in the cold. Thus, there were to be in each experiment one white man and one Eskimo, each in army clothing, and one Eskimo in fur clothing. The experiment was then to be repeated on the same men, but with the Eskimos having their clothing changed; i.e., the one who had had the army uniform on in the first test was to wear his fur clothing in the second test and vice versa. If fur clothing could be procured, the white man was to wear it in the second test.

This plan may be criticized on the grounds that, since no control could be exercised over the weather, the second experiment would not be a true check on the first one. This criticism is acknowledged. Yet, there is this value to the plan: it does exercise control over the clothing variable. The conclusions are then drawn, not from the responses of one man in two different garments in two experiments, but from the relative picture of three men in one test compared with the relative picture of the same three men in the second test.

As it turned out, the plan could not be carried through. In the first place, in only 4 tests could it be arranged to have two Eskimos in each. In 2 of them both wore the army uniform because neither one brought along the full regalia he usually wore on the trail. In the other 2 tests the Eskimo wore either army or fur clothing. In the second place, only 4 of the Eskimos could arrange or would volunteer for a second test, but in no case could they be paired with the same men as in the first test.

2. Procedure. The same procedure was followed in all tests, except that the weight and linear measurements were made only the first time a particular man acted as subject.

a. The subject stripped and his nude weight and height were measured on a clinical scale in the hospital.

b. He then lay down and the linear measurements necessary for computing regional surface areas by DuBois' formulas were made with a tape measure.

c. The subject then covered himself and relaxed for 10 minutes or more, following which the pulse rate and brachial arterial pressures were measured, usually only once. The subject then stood for exactly one minute, and during the 1 to 1½ minutes after standing the pulse and pressures were again measured.

In the actual performance, two factors occasionally intervened to militate against complete control.

(1) Although the hospital was always warm, it was not uniformly so. Therefore, not infrequently when the nude subject stood up from under his covers, his vessels responded, not only to the effect of gravity, but also to the sudden slightly cool feeling of the skin. Nothing much could be done about this matter as time and the other preparatory procedures necessitated that the subject be in the nude.

(2) The white subjects sometimes had difficulty in remaining quiet during the initial 10-minute rest period. Interruptions provoked vocal responses of various kinds which presumably could affect the heart rate. For this reason the white subject sometimes had to lie on the bed for more than 10 minutes but, on the other hand, prolonged attempts at relaxation often led to restlessness.

d. The thermocouple harness was applied and the subject was assisted into his garments. If he was wearing fur clothing, notations were entered at this time as to each item worn.

e. The subject sat down and his skin and rectal temperatures were measured. This had to be done as quickly as possible, because a man in full arctic assembly soon starts to sweat at normal room temperature. As a rule the subject showed perspiration on his forehead before he went outdoors.

f. The subject went outdoors and sat down with his back to the prevailing wind. Thereafter temperature measurements were made on him as often as possible, and subjective reactions were noted periodically. It was desired that exposures last to the limit of endurance. This desire was not usually fulfilled for the following reasons:

(1) The subjects, both white and Eskimos, became bored with just sitting outdoors.

(2) The occurrence of a social event would make the men want to finish the test in a hurry.

(3) The observers, particularly the one who was operating the potentiometer, would become fatigued especially if the test lasted after midnight.

g. At the termination of the exposure the subject went inside, and as he undressed the status and location of each thermocouple was checked. Refreshments were served and the subject was interrogated.

B. Apparatus and Methods

1. Thermocouples. Copper-constantan thermocouples were applied to the skin by means of a harness devised by Palmes (1947). Since the couple

is soldered to the middle of a brass screen, usually 5/8" by $2\frac{1}{4}$" in shape, the couple indicates the temperature of an area of the skin. In this manner the temperature was obtained on the plantar surface of the big toe and of the arch, anterior and posterior thigh, abdomen and lower back, and the volar surface of the distal phalanx of the large finger. In addition, a couple was placed on the exposed cheek by means of a wand about 2 to 5 minutes before the measurement. This couple gave the temperature of essentially the point of skin under it. The rectal couple was on the surface of a short plastic rod and was inserted 4 to 8 inches.

The leads from the couples terminated in the receptacle halves of Jones plugs. The extension lead ran from the potentiometer indoors through a port in the window to the outside. One observer then hooked up each subject in turn. As snow usually infiltrated into the receptacles of the plugs, the outdoor observer had to manipulate the halves of the plugs until contact was achieved. This could be communicated to him only by shouting through the window porthole. The rapidity and number of measurements which could be made were thereby reduced.

2. Potentiometer. The potentiometer was constructed at the Fort Knox laboratory in such a manner as to eliminate the use of a standard cell. (Exposure of a standard cell to low temperatures, even during transport, would make it unfit for further use.) Balance was indicated by a sensitive, portable galvanometer having a microscope.

3. Meteorology.

a. Air temperature was measured every 10 to 15 minutes with an exposed thermometer. Inasmuch as snow and frost often accumulated on the bulb producing unknown wet-bulb effects (which may have been negligible), it was decided to use the readings of the Weather Bureau station which was situated only 200 yards from the test site. As a rule, the two measurements agreed closely.

The subjects sat within the space encompassed by the L-shaped hospital, about 15 to 20 feet from the walls. The building was one story high. Thermocouple measurements showed that the temperatures of the walls and windows were slightly higher than the concurrent air temperature. This wall effect on radiant heat loss was considered negligible.

b. Wind velocity was measured every 10 to 15 minutes with an anemometer borrowed from the Navy. The graduations did not go lower than 3 knots. Also, it operated like an automobile speedometer and indicated instantaneous speed without totalizing the air movement over an interval of time. Thus, the average wind velocity could only be estimated roughly. Although a definite wind direction could usually be felt, there was also considerable turbulence due to the building. Hence, the anemometer was always held to one side of the subjects and at about head level. Air movement around the feet was probably less than that at the head.

c. Precipitation. No measurements or notations on snowfall were made. Very often the wind whipped up the snow and blew it around.

d. Sunshine and overcast. In December and early January the sun never rises above the horizon at Barrow. Moreover, practically all

tests were performed after 1900 hours. No observations were made as to overcast, although sometimes the aurora was brilliant.

4. Clothing

a. The army clothing worn was that designated as uniform #6, and was the warmest army assembly. It was meant to be worn for an expected temperature of -60°F. The individual garments are itemized in Table 1.

Actually, this assembly provided more insulation than the Army prescribed for the air temperatures prevailing at Barrow. Using temperature as the sole criterion, the uniform #5 should have been used, which is to be worn when the minimum temperature expected is -35°F. and the maximum temperature is +15°F. It is not possible to change the #6 assembly in every detail to have the prescribed items of the #5 assembly. Although at Fairbanks, where wind is negligible, the air temperature criterion alone is adequate; at Barrow the cooling effect of the wind must also be considered. Therefore, the uniform #6 was used.

b. Eskimo clothing. Five Eskimos wore their own clothing which they used in hunting and trapping. Their assemblies were not uniform in every detail but, as an example, the garments of one subject are itemized in Table 2.

Some notable features of the Barrow Eskimo clothing were:

(1) The undergarments are those of the white man and usually made of cotton.

(2) Only the outer garments are made of fur.

(3) The parkas do not extend downward as an apron in front and back, as usually seen in pictures or museum displays of Eskimo clothing. The Barrow Eskimo places a piece of fur on the snow or ice before sitting down. (This we were told by them but never observed.)

(4) The fur trousers end in a 2 to 3-inch band just below the knee and do not extend down to the ankles. It would be impossible to expose the knees by pulling the trousers upwards.

(5) The fur trousers may be tailored to form a pocket-like bulge over the knee. Thus, the air layer is not pressed out in the sitting position.

c. It is difficult to form a satisfactory mental comparison of the army and Eskimo clothing by merely reading the lists in Tables 1 and 2. Moreover, the number of pieces put on do not indicate the amount of covering over the junctional regions where there is overlapping. For example, the waist is covered by both the upper and lower garments. The skin over the upper abdomen, therefore, would be expected to be warmer than the skin over the thigh, even if the heat flow to both places were the same. To facilitate

TABLE 1

OFFICIAL UNIFORM #6, TASK FORCE FRIGID

Upper Garments

1. Undershirt, wool, 50%, OD
2. Shirt, flannel, OD, coat style
3. Sweater, wool, OD, high neck
4. Jacket, field, pile, OD
5. Parka, field, pile, OD
6. Parka, field, cotton, OD

Lower Garments

1. Drawers, Wool, 50%, OD
2. Trousers, field, wool, OD, serge, 18 oz. sp
3. Trousers, field, cotton, OD, w/suspenders
4. Belt, web waist

Footwear

1. Socks, wool, cushion sole (1 pr)
2. & 3. Socks, wool, ski (2 pr)
4. Socks, felt (1 pr)
5. Insoles, felt (1 pr)
6. Boots, mukluk

Handgear

1. Mitten, insert, wool, trigger finger
2. & 3. Mitten, Arctic (contains an insert)

Headgear

1. Cap, field, pile, OD (flaps down except on forehead)
2. Hood, parka, pile with fur ruff
3. Hood, parka, cotton

TABLE 2

EXAMPLE OF ESKIMO CLOTHING

Upper Garments

1. Undershirt, cotton
2. Shirt, cotton, cambric
3. Parka, caribou, fur in, lined
4. Parka, caribou, fur out

Lower Garments

1. Drawers, cotton
2. Trousers, cotton, gabardine
3. Trousers, caribou, fur out
4. Belt, leather

Footgear

1. Socks (1 pr)

    a. Caribou, fur in, on soles
    b. Sheep, fleece in, from middle of lower legs down over dorsum of feet.

2. Mukluks, caribou

    a. Leg portion, fur out
    b. Soles, fur in

Handgear

1. Mittens, fawn, fur in
2. Mittens, dog, fur out

Headgear

1. Hood, parka, caribou, fur in, lined, wolverine ruff
2. Hood, parka, caribou, fur out, wolf ruff

the comparison of army and Eskimo clothing, the number of layers covering different parts of the body is given in Table 3.

Clothing provides insulation by trapping air, both in the fibers and meshes of the fabric and also between the layers of fabric. Table 3 compares only the number of layers of fabric. Clearly, there are more layers in the army than in the Eskimo assembly, chiefly because of the sweater, pile jacket, and the several pairs of socks. (The active white man may shed some of the items of clothing to avoid sweating.) If both assemblies provide the same amount of insulation, it follows that fur provides a thicker mesh of trapped air than the material of the army uniform.

d. One more fact about clothing must be described. On the first day of testing (27 December), the subjects sat outdoors on uncovered metal chairs. Considerable cooling of the buttocks and posterior thighs took place by conduction, as attested by both the subjective sensation of pain in the buttocks and low thigh temperatures. On all subsequent days a navy wool blanket folded into 16 layers was placed on the seat of each chair. The buttocks were no longer painful and the thigh temperatures fell only a little.

5. Test Subjects

A total of 5 white men and 10 Eskimos took part in the tests. Two more Eskimos had volunteered but they contracted upper respiratory infection before their scheduled day and were not used. One white man was a Norwegian and claimed to have lived in the North country all his life. He was an outdoor worker for the Navy. The other four white men had spent only two to six weeks in the Arctic prior to the test, although one was in the Yukon Territory during 1942-43.

Certain data about the physical aspects of the subjects are given in Table 4. Attention is called to the following facts:

a. Only 7 men were pure Eskimos; two were 3/4 Eskimo and 1/4 white; one was 1/2 Eskimo, 1/2 white.

b. Two of the Eskimos had sedentary occupations indoors; six were definitely outdoor workers. The duties of the two soldiers were not ascertained.

c. The white men were larger, on the average, than the Eskimos, but the mass per unit area was not significantly different between the two groups.

d. The percentage of the surface area over the different parts of the body was the same in the two groups. These regional areas were calculated according to the formulas of DuBois andDuBois.

C. RESULTS

A total of 9 tests on 7 different days was performed; 14 Eskimo exposures were obtained. They will not be discussed in detail in this report because experiments are now being conducted in the Fort Knox laboratory to determine how best to analyze the data obtained at Barrow. The initial superficial examination of these data did not disclose any consistent

TABLE 3

LAYERS OF CLOTHING

	Army Uniform #6	Eskimo
Thorax	6	4
Waist	9	7
Lower Abdomen and Back	5	5
Thighs Upper	5	5
Lower	3	3
Legs	4	3
Above Ankles	7	3
Ankles and Dorsum of Feet	5	2
Soles	6	2
Arms	6	4
Distal Third of Forearms	9	6
Hands and Wrists	3	2
Head	3	2

TABLE 4

PERSONAL DATA ABOUT TEST SUBJECTS

Name	Age years	Weight pounds	Height inches	Surface Area sq. meters	Weight S.A. kgm/sq.m	Occupation
ESKIMOS						
Bert Ahmaolik	38	154.	65.	1.76	39.77	Hunter
Noah Itta	27	155.	62.5	1.[illegible]	3[illegible].32	Hunter
Clay Kaigeluk	31	140.5	65.	1.71	37.35	Hunter
Hoover Koonaloak	28	161.	66.	1.83	41.7[illegible]	Pfc, USA, Hunter
Ned Nusunginya	48	145.3	63.3	1.69	39.00	Outdoor labor for Navy
Nathaniel Olemaun	30	160.3	67.	1.[illegible]	39.60	Pfc, USA
Fred Ipalook	36	176.	63.[illegible]	1.85	43.[illegible]4	School teacher; does not hunt
Alfred Hopson[1]	48	150.8	67.	1.80	38.08	Hunter
Eddie Hopson[2]	26	147.5	66.5	1.77	37.[illegible]8	Outdoor labor for Navy
Harold Kaveolok[3]	29	130.5	6[illegible].3	1.62	36.62	School teacher for past year
MEAN	34	152.	65.5	1.77	39.17	
MEAN FOR PURE ESKIMOS	34	156.0	65.5	1.79	39.[illegible]7	

1. Half white, half Eskimo (father an Englishman)
2. One quarter white, three quarters Eskimo (mother is Eskimo)
3. One quarter white, three quarters Eskimo (mother half Irish)

Name	Age years	Weight pounds	Height inches	Surface Area sq. meters	Weight S.A. kgm/sq.m	Occupation
WHITE SUBJECTS						
R.H.V.	26	1[illegible]2.9	72.	2.0[illegible]	3[illegible].97	Captain, MC
E.L.D.	30	155.3	67.5	1.[illegible]7	37.74	Lieutenant, MC
H.I.F.	39	132.	66.	1.6[illegible]	35.71	Major, SnC
[illegible].C.H.	26	20[illegible].5	71.0	2.17	43.67	Lt., DC, USNR
F.H.	45	155.	67.3	1.[illegible]	3[illegible].71	Carpenter
MEAN	33	166.7	69.3	1.92	39.16	

differences between the Eskimos and the white men. Further study, however, seemed to indicate that proper curve fitting was important. Illustrative measurements will be given to show the problems involved in the analysis.

1. Cardiovascular Tests. The data are presented in Table 5. The following arbitrary classification of physiological states was used:

a. Optimal--increment of pulse rate less than 10; decrement of arterial pressures not more than -2.

b. Sub-optimal--increment of pulse rate 10 to 20 with decrement of pressures.

c. Poor--increment of pulse rate 20 to 30.

d. Very poor--increment of pulse rate more than 30.

Borderline cases were evaluated individually; for example, in Test No. 2, Noah was classed as sub-optimal, not as poor, because even though the increment of pulse rate was 20, the pressures increased by several millimeters.

On the basis of this arbitrary classification, the subjects started their exposures in the physiological states shown in Table 6. It appears that in four cases the white subjects were initially in a definitely poorer state than the Eskimos. In one test the Eskimo was in poorer shape than the white subject. In four tests the subjects were on about equal terms.

The term <u>physiological state</u> as used here is meant to denote the integral of internal factors which determine the efficiency with which the organism can cope with a stress, and can be of transient duration. The term, <u>physical fitness</u>, usually connotes a somewhat permanent condition. Among the test subjects, Fred, who is a sedentary individual, was in both a poor physiological state and a poor physical condition. ELD, however, can be considered to have been in good physical condition but in a good physiological state only for his first test. Some of the internal factors which determine the physiological state are circulatory, respiratory, hormonal, nervous, muscular, digestive, etc., in nature. The circulatory state is the one most commonly used as an index. It remains to be proved, however, that the cardiovascular test here used bears a close correlation with one's ability to endure or cope with cold weather. It is possible that severe cold can elicit an adequate response even from one initially in a poor physiological state.

It is interesting to note that both Ned and Alfred have low arterial pressures for their ages (both 46 years old), whereas FH (age 45) has the expected arterial pressures. Rabinowitch (1936) quotes evidence that the Alaskan Eskimos apparently do not have arteriosclerosis, although he did find definite signs of it among the Eskimos of eastern Canada.

2. Body Temperatures. Figure 1 shows the finger temperatures during exposure in Tests 1 and 2, both on 27 December. The air temperature was practically constant and the same for both tests, -23°F. (-30.5°C.). The wind velocity, however, was higher for the first test (about 11.5 mph.) than for the second test (about 7 mph.). In both of these tests the men sat on uncovered metal chairs. The rectal temperatures were essentially the same

TABLE 5

RESULTS OF CARDIOVASCULAR TESTS

Test No.	Date	Name*	Pulse Rate			Arterial Pressures		
			Recumbent	Standing	Δ	Recumbent	Standing	Δ
1	27 Dec	Dert	66	80	+14	114/76/-	118/80/-	+4/+4/-
1	27 Dec	HLF	66	100	+34	118/74/-	114/72/-	-4/-2/-
2	27 Dec	Noah	78	98	+20	128/72/-	134/80/-	+6/+8/-
2	27 Dec	Alfred[1]	56	64	+ 8	117/74/-	118/76/-	+1/+2/-
2	27 Dec	RBM	100	124	+24	138/72/-	128/80/-	-10/+8/-
3	28 Dec	Clay	76	78	+ 2	132/74/68	144/84/80	+12/+10/+12
3	28 Dec	WCH	76	84	+ 8	117/72/64	122/80/72	+5/+8/+8
4	28 Dec	Ned	78	84	+ 6	116/74/68	114/76/68	-2/+2/0
4	28 Dec	Hoover	66	82	+16	126/78/64	136/88/82	+10/+10/+18
4	28 Dec	Eddie[2]	64	80	+16	110/-/64	115/78/68	+5/-/+4
4	28 Dec	ELD	80	86	+ 6	128/78/68	132/84/76	+4/+6/+8
5	30 Dec	Fred	80	104	+24	134/110/100	130/104/96	-4/-6/-4
5	30 Dec	Harold[2]	64	82	+18	119/82/50	117/80/62	-2/-2/+12
5	30 Dec	ELD	86	114	+28	118/72/68	118/84/78	0/+12/+10
6	31 Dec	Alfred[1]	72	66	- 6	128/72/60	138/84/76	+10/+12/+16
6	31 Dec	RBM	76	92	+16	128/74/58	122/80/60	-6/+6/+2
7	1 Jan	Nathaniel	76	80	+ 4	120/78/70	128/80/72	+8/+2/+2
7	1 Jan	ELD	80	102	+22	134/80/72	132/90/80	-2/+10/+8
8	4 Jan	Fred	66	92	+26	128/84/78	130/82/76	+2/-2/-2
8	4 Jan	HLF	80	88	+ 8	134/78/64	118/82/68	-6/+4/+4
9	5 Jan	Ned	68	86	+18	108/60/56	108/70/62	0/+10/+6
9	5 Jan	Eddie[2]	70	80	+10	122/72/55	118/78/60	-4/+6/+5
9	5 Jan	FH	72	98	+26	142/92/82	140/98/88	-2/+6/+6

*English names of Eskimos and initials of white men.

[1] Half white, half Eskimo.

[2] One quarter white, three quarters Eskimo.

TABLE 6

PHYSIOLOGICAL STATES OF SUBJECTS AT BEGINNING OF EXPOSURE TO COLD

Test No.	Date	Name*	Physiological State
1	27 Dec	Bert	Sub-optimal
1	27 Dec	HLF	Very poor
2	27 Dec	Noah	Sub-optimal
2	27 Dec	Alfred[1]	Optimal
2	27 Dec	RBM	Poor
3	28 Dec	Clay	Optimal
3	28 Dec	JCH	Optimal
4	28 Dec	Ned	Optimal
4	28 Dec	Hoover	Optimal
4	28 Dec	Eddie[2]	Optimal
4	28 Dec	ELD	Optimal
5	30 Dec	Fred	Poor
5	30 Dec	Harold[2]	Sub-optimal
5	30 Dec	ELD	Poor
6	31 Dec	Alfred[1]	Optimal
6	31 Dec	RBM	Sub-optimal
7	1 Jan	Nathaniel	Optimal
7	1 Jan	ELD	Poor
8	4 Jan	Fred	Poor
8	4 Jan	HLF	Optimal
9	5 Jan	Ned	Sub-optimal
9	5 Jan	Eddie[2]	Optimal
9	5 Jan	FH	Poor

* English names of Eskimos and initials of white men.

[1] Half white, half Eskimo.

[2] One quarter white, three quarters Eskimo.

for all of the men. They are plotted, however, only for Bert and Alfred, and without showing the individual observed points.

Attention is called to the following details of Figure 1:

a. Noah, in army clothing, appears to have maintained a warmer finger than Bert in his own fur clothing. The difference, however, does not necessarily indicate that the army handgear is superior to the fur mitten, because Noah also started with a warmer finger. In another test, the Eskimo with fur mittens had a warmer finger than the Eskimo with army handgear.

b. Even allowing for Noah's high initial temperature, both he and Bert maintained significantly higher finger temperatures than the two white men (HLF and RBM) and Alfred in army clothing.

c. Alfred was in an optimal physiological state, yet his finger temperature was the same as those of the white men who were in a poor physiological state. (The curve for Alfred was not drawn because it lies almost exactly over the one for RBM, except for the last point.) Perhaps the cardiovascular test used is incapable of indicating one's potential for resisting the cold.

It is notable that Alfred is one-half white and one-half Eskimo, and also that when we first met him he informed us that he was more miserable in the cold than the other Eskimos.

d. Curves were fitted to the observed data by plotting them on semi-log paper and connecting them by straight lines. Equations of the type $Y = ab^X$ were then fitted by the method of least squares to those points which fell on or close to straight lines in the semi-log plot. For Noah, Alfred, HLF and RBM, there were 3 or 4 points each thus fitted to exponential curves. For Bert, however, two curves were fitted to two points each. Obviously, any kind of curve can be drawn through two points. The reason for drawing exponential curves through the points was that, according to Newton's law of cooling, the rate of heat flow from an object to its surrounding is proportional to the difference in temperature between them; i.e., the object cools exponentially. In some of the tests, however, the data seem to fit better to parabolic or hyperbolic curves than to exponential curves. Hence, before drawing final conclusions, the course of cooling in the Fort Knox laboratory under conditions simulating the Barrow tests is being measured at frequent intervals in order to determine how best to fit curves to the Barrow data.

It is hoped that properly fitted curves will make it possible to locate with some accuracy the points of inflection which can be interpreted to indicate vasoconstriction or vasodilatation. For example, in the case of Bert the initial, gently falling, freehand curve suddenly falls steeply at about 45 minutes of exposure. This sudden change in the fall of temperature was probably due to vasoconstriction. Similarly, the inflexion at 95 minutes was probably due to vasodilatation.

III. DISCUSSION

The Barrow Eskimos gave the general impression that they were much happier in the outdoor cold than the observers were, both in the tests and in ordinary living. Some of the Eskimos felt that the conditions of the tests

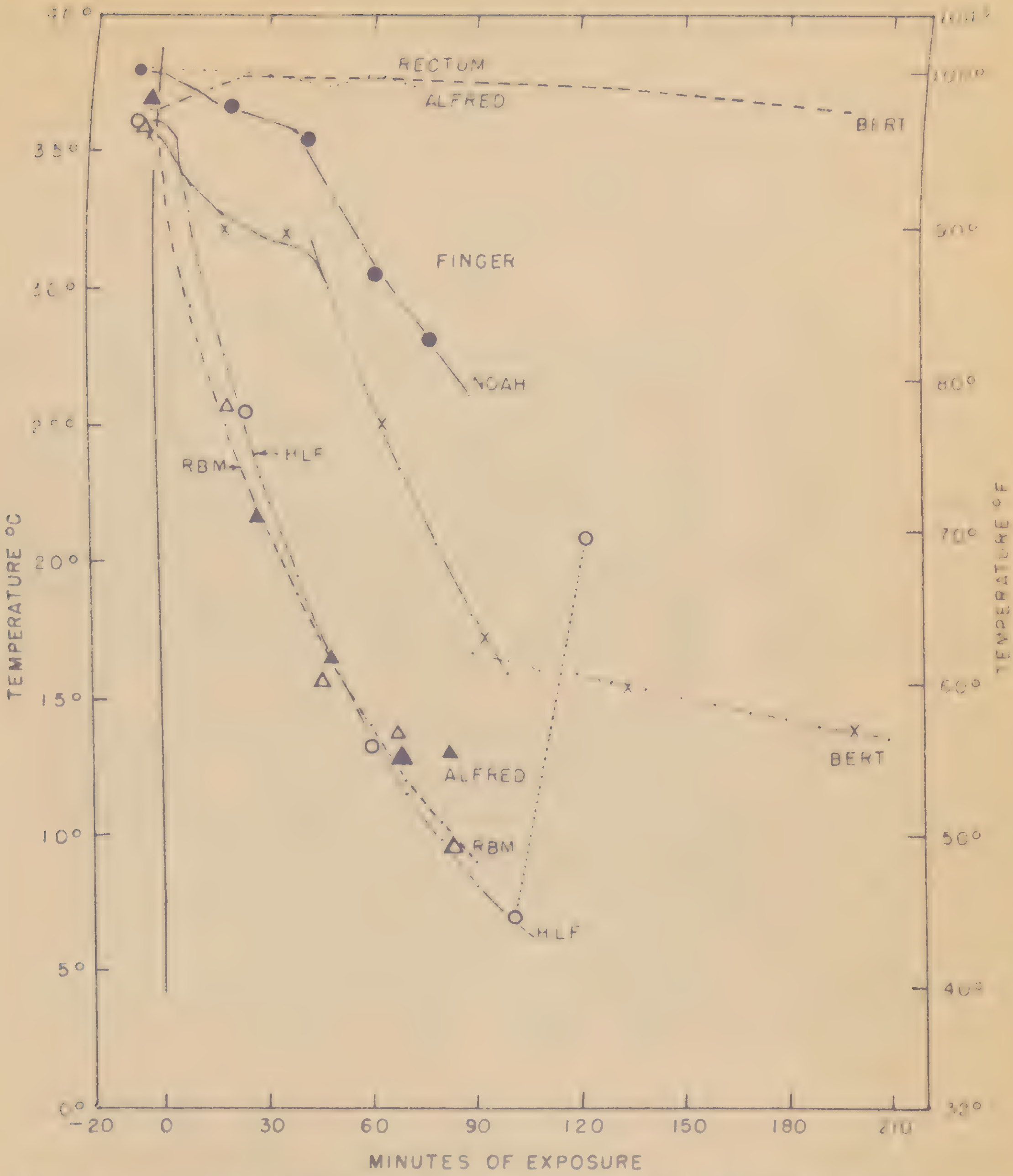

Fig. 1. Finger temperature during exposure to outdoor weather.
Air temperature, -23°F. (-30.5°C.). Wind velocity, 7 to 11.5 mph.
Tests 1 and 2, 27 December 1946.

X Bert in fur clothing, sub-optimal physiological state, Test 1
● Noah in army clothing, " " " " , Test 2
▲ Alfred in army " , optimal " " , Test 1
○ HLF " " " , very poor " " , Test 1
△ RBM " " " , poor " " , Test 2

The men went outdoors at zero time.

were almost as severe as any that they usually encountered. Although they too were often made uncomfortably cold, their subjective reports and general picture did not convey as much discomfort as shown by the white men.

The results of the tests indicate that, although during vasoconstriction the finger of an Eskimo cools at about the same rate as the finger of a white man, the Eskimo maintains a warmer finger than the white man during exposure by delaying vasoconstriction. The Eskimo's mechanism seems to leave him happier in the cold than the white man is left by his responses. It is emphasized that this interpretation of the data is purely tentative.

The Eskimos may have acquired their vascular responses to cold either by inheritance or by acclimatization. As to the influence of heredity, it is notable that Alfred, a half-breed, showed the same finger temperature as the white man (Fig. 1), and also claimed that he was not as comfortable in the cold as the other Eskimos. As to the influence of acclimatization, the Norwegian subject who said he had lived in the North all of his life did not keep his finger as warm as the Eskimo with whom he was paired, but did make a better showing than the other white men did. Furthermore, Ned (a full Eskimo) thought that after repeated exposure the white man came to endure the cold as well as, or even better than, any Eskimo. He based his conclusion on the observation that the white men working in the Navy camp at first wore heavy handgear, but subsequently could perform the same duties with only canvass gloves. He thought the white man was often better outdoors because he worked much harder than the Eskimo.

The investigators do not imply that their findings necessarily apply to all Eskimos and to all white men, but restrict their conclusion to only those who were studied. It is possible that there are white men who possess the Eskimo type of reaction to the cold or who may acquire it by acclimatization. The important point is that men who give every indication of great hardihood in the cold (in this study the pure-breed Eskimo outdoors-men of Barrow) maintain warm fingers for the first 1 to 3 hours of exposure. This observation is of value in lending direction to laboratory studies of acclimatization, and also in giving an indication as to the physiological characteristics to be considered in preselecting men for duty in the Arctic. Their greater comfort is ascribed to the relatively higher finger temperatures which they maintained in the cold.

IV. CONCLUSIONS

Full-breed Eskimos of Barrow appeared to bear the cold weather better than the white men paired with them. Their greater comfort is ascribed to the relatively higher finger temperatures which they maintained in the cold. This conclusion is tentative pending the analyses of similar tests performed on white men in the Fort Knox laboratory.

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PART II

WATER BALANCE STUDIES AT TASK FORCE FRIGID AND TASK FORCE WILLIWAW

I. INTRODUCTION

The chief stress impinging upon men who are in the field in the Arctic is the cold weather. If, however, they are in the field continuously for several days, cold can cause other factors to become stresses and the physiological and psychological debilitations which arise may be due to these indirectly induced stresses instead of to the cold weather directly. These induced stresses may be fatigue and exhaustion due to constant work and shivering; insufficient sleep due to the inability to sleep in a cold tent; inanition and dehydration due to inability to eat and drink in the cold. Naturally, if all the comforts of home are taken out into bivouac, the indirect stresses will not make their appearance. On the other hand, if the bivouac conditions are rugged and severe, all of the stresses should be taken into account and the physiological strains should not be laid to cold weather alone.

It is not a simple and easy matter to obtain significant physiological observations on men who are subjected to the rigors of the Arctic. Because facilities were necessarily limited, it was decided to center observations around the problem of water balance, which could be studied by adapting the methods used by Adolph in the desert (Adolph and Associates, 1947). The object was to see if men would keep themselves in water balance under conditions of no liquid water supply.

Water supply in the Arctic is a serious problem even if water is everywhere in the form of snow. Transportation of liquid water from a water point requires heated, insulated carriers. Men can, of course, melt snow if they have a stove and fuel but the stimulus to do so must be stronger than the stimuli of the environment which make the task a chore. Speert (1943), for example, thought that he and his party suffered from dehydration while in an isolated bivouac for a week on the Tanana River. His evidence was that everybody lost weight. It is, therefore, apparently quite possible, though not proved that men can go into negative water balance in the Arctic if forced to rely upon natural sources for water.

Dehydration in a comfortable environment produces effects which may or may not occur in a cold environment, but which are instructive. Black, McCance and Young (1944) studied dehydration in men and women by withholding water. The subjects continued in their normal laboratory routine. By the end of 3 to 4 days they suffered 5 to 6 per cent dehydration, and "exhibited a change in behavior which could be interpreted as an exaggeration of their temperamental type. Serious people became positively somber; while others, normally cheerful, exhibited a somewhat hollow vivacity. The subjects were intellectually capable of performing estimations and calculations, but their concentration was impaired. They found that the days of dehydration were not actually uncomfortable but they seemed very long. They were never unbearably thirsty, but by the third day their mouths and throats had become dry, their voices husky, and they had begun to find it difficult to

swallow. By the third or fourth day their faces had become somewhat pinched and pale, and there was a suggestion of cyanosis about their lips which was rather characteristic."

At this juncture it is interesting to inquire how the Eskimos cope with the water problem. It is often said that Eskimos have a high water intake. "On one point only do they display a lack of moderation, and that is with regard to water drinking; a lot of water, and that ice-cold, is considered to be a necessity. This, however, is probably connected with their specialized meat diet, and the constant swilling undoubtedly saves them from a lot of rheumatism in their old age." (See Birket-Smith, 1935.) "The habitual drink is water, which these people consume in great quantities when they can obtain it, and like to have very cold. In the winter there is always a lump of clean snow on a rock close to the lamp, with a tube under it to catch the water that drips from it. This is replaced in summer by a bucket of fresh water from some pond or lake. When the men are sitting in their open air clubs at the summer camps there is always a bucket of fresh water in the middle of the circle, with a dipper to drink from. Hardly a native ever passed the station without stopping for a drink of water, often drinking a quart of cold water at a time. When tramping about in the winter they eat large quantities of ice and snow, and on the march the women carry small canteens of sealskin, which they fill with snow and carry inside of their jackets, where the heat of the body melts the snow and keeps it liquid. This great fondness for plenty of cold water has been often noticed among the Eskimo elsewhere, and appears to be quite characteristic of the race." (Murdoch, 1892.)

Can one literally believe these statements, and others comparable to them, made by non-physiologists? To our knowledge, nobody has yet measured systematically the water exchanges of Eskimos, and the only quantitative estimate of water intake that we have found is the one quoted above from Murdoch. There are two key statements in this quotation which we underscored. They suggest the possibility that the Eskimos appeared to drink a lot of water because, when they came before white men, they were already partially dehydrated and therefore quickly replenished the body deficit from the white men's supply of water. This possibility is not absurd, for Murdoch's senior officer wrote of the same expedition: ".... and as the season advanced and water became scarce we were daily besieged by the seal hunters coming from the sea and begging for a drink of water, of which there is a great scarcity after the frost has sealed up all sources of supply. The scarcity of fuel, together with their inadequate means for melting ice and snow, causes them to suffer under a constant water famine from October to July, and they seemed to think that our supply was never failing." (Ray 1885.) Anyone who has climbed the ice-hummocks of the Arctic Ocean to go seal hunting can appreciate that much sweat can be produced in this exertion.

Heinbecker (1928, 1931, 1932) obtained 24-hour urinary collections from 10 Eskimos on Baffin Island. For experimental purposes, the subjects were kept in the fasting state, but were allowed to drink water. Hence, his data (473 to 2955 cc., average 1205 cc. per 24 hours) do not give a valid indication of normal water turnover among Eskimos. Rabinowitch and Smith (1936) found that urinary specimens (not 24-hour collections) from the Eastern Eskimos had low chloride concentrations and an average

specific gravity of 1.015 (1.010 to 1.024). They ascribed the low urinary chloride concentration to the low salt content of a meat diet and to profuse sweating. We were unable to study the water economy of our Eskimo subjects, because the necessary equipment had not arrived from Fort Knox before we left for Barrow.

The above quotations emphasize that Eskimos prefer cold water. Other writers say that Eskimos drink hot tea. One of the Barrow Eskimos (Ned) informed us that when on the trail he drank warm coffee from a thermos bottle. He appeared to be amazed that we should consider such a reasonable procedure as extraordinary and unexpected.

There are three fundamental problems concerning water balance which need to be solved:

1. How well do men maintain their water balance when in the field in the Arctic, and what deleterious effects do they suffer from imbalance?

2. What factors (environmental, psychological, thermal, circulatory, renal, gastro-intestinal, and dietary) influence the turnover of water in cold environments?

3. What are the water requirements for different levels of performance?

Some aspects of these problems can best be attacked in the laboratory; others can be studied only in the field.

An army which operates from a comfortable garrison and merely sallies forth into the field for a few hours a day will not have to worry about water balance. At Frigid every small unit, which we visited and which worked outdoors only during the daylight hours, carried along coffee in an insulated container. This seemed to us an excellent practice. At Williwaw, coffee was prepared for the men both in the morning and in the evening, even though the tactical situation required that they subsist on field rations alone. Different men drank different amounts of this prepared coffee. The value of it was probably largely psychological. Physiological benefits probably also accrued, although the amount of heat added to the body in this manner is very small; 500 cc. of liquid at 50°C. will add only 6 or 7 Calories. It is possible that caffeine stimulates the central nervous system directly. We suspect, however, that stimulation comes from just warming the stomach, which reflexly produces a brighter outlook.

II. EXPERIMENTAL

A. General Design of Program

1. Total water intake and urinary output were to be followed in men continuously in the field. Obviously, if the men were to return every night to their barracks, there would be no problem of water balance.

2. The men would have to procure water for themselves from natural sources. Obviously again, if water were provided there would be no real problem.

3. The men would be free to drink as much water as they bothered to procure. The object was to see if they would maintain an adequate water intake and not to ascertain the effects of diverse amounts of controlled intake

4. Because a significant amount of water might be in the food, all men would be on the same ration, preferably the Army Field E Ration, to facilitate a reasonable estimation of food water.

5. The major exertions of the men would have to be the same for all, but the milder forms of activity, including sleep, would not be controlled.

6. Dehydration, if any, would be deduced from changes in body weight, relative values of water intake and urinary output, and changes in blood specific gravity.

7. Physiological deterioration, if any, would be deduced principally from changes in heart rate following the performance of standard work.

8. If opportunity permitted, the observations would be performed on the men while in the barracks both before and after going out into the field.

9. Observations would be limited to ten men, because there were only three observers, and because the measurements had to be accurate.

With these ideas in mind, water balance observations were conducted with both Task Force Williwaw and Task Force Frigid. Because the conditions were not the same with the two Task Forces, a comparison of the results is instructive and interesting.

B. <u>Materials and Methods</u>

1. Water Intake.

a. Imbibed water. Each subject was provided with a graduated enameled cup and a pocket notebook. The men were instructed to measure all fluids and to enter the amounts drunk in their notebooks. The entries were repeatedly checked during the course of the test.

At Task Force Williwaw, water was obtained by breaking through the thin surface ice of a lake and dipping in with a cup. The water was thus icy. At first the hole was broken through with the heel but later an ax was used. It was necessary to walk about 200 to 400 feet to the lake, including an embankment of about 20 feet. Thus the chief stimuli inhibiting the procuring and drinking of water were:

(1) The distance necessary to traverse, including an embankment, to the source of water.

(2) The necessity for dislodging oneself from a more or less comfortable position (wind-break, tent, or sleeping bag) and exposing oneself to the wind. This stimulus was strong enough to inhibit some men from going for the hot coffee provided on two occasions.

(3) The nuisance of having to break through the ice. Actually, this was not much of a task but it was an annoying one in the wind.

(4) *The almost inevitable slight wetting of one's handgear when dipping in for the water.*

(5) *The low temperature of the water. One does not drink much ice water, particularly if one already feels cool. Heating water for coffee took time and effort,*

(6) The absence of a positive stimulus should be noted. The atmosphere of a small tent or of a windy outdoors is not conducive to drinking.

These inhibiting stimuli appear minor when considered singly, but together they summate to produce an effect that makes one pause before dashing out for water. No doubt, had we not been concerned with the water balance problem, we might have merely reacted to them but not noted their influence on the behavior of men.

At Task Force Frigid, water was obtained solely by melting snow. It was originally intended that each man be provided with a one-man gasoline (Coleman)stove. Only three could be procured, however, including one sent up from Fort Knox. As it turned out, these stoves were used for melting snow only for the noon meal when out on the march. The rest of the time snow was melted on two other stoves. One was a coal-burning, pot-bellied stove used for heating the pyramidal tent. Some of the men placed their cups containing snow on top of this stove and left them there until they desired to drink. The second stove was a gravity-feed, gasoline one. It had as a top a metal tray about 3 x 1[illegible] x 1[illegible] inches, and was provided as a facility for heating the E-ration, which was always frozen. The sergeant, however, spontaneously detailed a man each day to keep the tray filled with snow. Thus the men in the Frigid study had no real difficulty getting water.

b. Water content of food. E Ration was the only food eaten and the amount of each item was recorded in notebooks. The amounts of carbohydrate, fat, and protein in each item were obtained from Quartermaster food tables. The sum of these was subtracted from the weight of the food and the difference was assumed to be the water content. The E Ration tables also gave the caloric value of the food.

2. Urinary Output.

a. Each subject was provided with a conspicuously numbered one-half gallon can. A metal funnel and large handle were soldered to each can and a stopper with handle was chained to it.

b. Volume was measured in a liter-size graduated enameled cup. It was necessary to melt the urine before the volume could be measured.

c. Specific gravity was measured with a urinometer. Unfortunately, the spindles were not calibrated before use and they were broken before they could be later calibrated in the laboratory. Hence, the small temperature corrections which were made were perhaps of little value.

d. A sample of each 24-hour collection of urine was saved for later chloride analysis in the laboratory by a modified method of Van Slyke.

e. Total urinary solids were estimated on the basis of specific gravity and volume. Instead of using Long's coefficient (Long, 1903), his

data were used to calculate a curve by the method of least squares. The curve was used in obtaining the values for solids.

3. Psychological Orientation.

The test subjects were not volunteers. Since the collection of the fundamental data had to be left to them, it was necessary to adopt measures which would insure the validity of the data. Although military command was, of course, the chief stimulus for keeping the men in hand, it was feared that reliance upon it alone would prove to be inadequate. For this reason the following additional tactics were employed:

a. Before going into the field the men were briefed with emphasis on the following points:

(1) That the test was important and would yield valuable information.

(2) That only by adhering rigidly to the directions of the test could results of value be obtained.

(3) That both the men and investigators were wasting their time and undergoing unnecessary misery unless the test was carried to a successful completion.

(4) That all men make mistakes but that all mistakes should be reported to the investigators.

b. During the course of the test, active cooperation was solicited by:

(1) The investigators exposing themselves to the same rigors as the men.

(2) Friendly and courteous greeting and frequent questioning about their welfare.

(3) Frequent checking on the little matters (did the wind blow away some of your broken cracker before you could eat it?).

(4) Bothering to answer or comment upon many little questions and remarks.

(5) Trying to establish the impression and atmosphere that the test was something out of the ordinary and of great importance:

(a) The individual parts of the test were executed with organization and efficiency.

(b) Tremendous interest was always expressed in the data as they were gathered. In this way, the men themselves came to be interested in their weight changes, pulse rates, etc.

(c) *The spontaneous appearance of high ranking officers was of great value in adding significance to the test.*

4. *Body Weight.*

Body weights were measured in the nude on a scale accurate to ±10 grams. Unfortunately, the urinary bladder was not always certainly emptied prior to weighing. At Task Force Williwaw it was out of question to carry the heavy scale over the mountains, and the weights were obtained only just before and after the march. At Task Force Frigid the men were trucked to the dispensary and weighed about an hour after breakfast on four mornings.

5. Blood Analysis.

Elaborate analyses were out of question and only simple ones could be performed. Potassium-ammonium oxalate was used as anti-coagulant. Blood was drawn from the antecubital veins without stasis.

a. At Task Force Williwaw, only bottles of copper sulfate were available for measuring blood and serum specific gravities by the method of Phillips <u>et al</u>. (1945). Unfortunately, an error had been made in weighing out the salt and new bottles could not be made up. The results, therefore, are of no value.

b. At Task Force Frigid, blood samples were drawn during 1 to 1½ hours after breakfast, except on day 5 in bivouac when they were obtained before breakfast. The following measurements were made: (1) Plasma specific gravity by means of a dipping refractometer. Melted icicles were used for distilled water. (2) Blood and plasma specific gravities by the copper sulfate method. Corrections were made for the effect of the anticoagulant. (3) Hematocrit ratio: The samples were spun for 45 minutes in a large centrifuge. Sedimentation rates were obtained before centrifuging.

6. Meteorology.

a. Task Force Williwaw. Only dry-bulb temperatures were measured on the march and notations were made about sunshine, wind, and precipitation. The wind varied greatly from place to place. The following data summarize the daytime weather briefly:

Date	Air Temp.	Wind	Sky
16 Jan.	27.4°F.	Light	Mostly overcast
17 "	23.8°F.	Light	Sunny with passing clouds
18 "	27.7°F.	Strong	Mostly overcast
19 "	27.4°F.	Very strong	Completely overcast
20 "	22.0°F.	Strong	Mostly overcast

Whenever the sun was out one felt subjectively warmer. Although the air temperature was usually only a few degrees below freezing (never above freezing), a strong wind always cooled the resting man to the point of being uncomfortable. Precipitation was always snow, and it was sometimes difficult to tell whether snow was falling or merely being whipped around by the wind. At night the temperature fell to 14°F.

b. Task Force Frigid. Air temperature was measured, but the wind velocity was so low, usually less than one mph. at 4 feet above the ground (with a totalizing anemometer), that measurements were not made. During the 5 days in bivouac the air temperature was unseasonably warm. The following data summarize the weather:

Date	Air Temp. Day	Air Temp. Night (min.)	Sky
26 Feb.	32°F.	20°F.	Sunny, but bivouac in shadow of woods
27 "	30°F.	20°F.	Overcast, light snow till noon
28 "	28°F.	13°F.	Sunny in morning only
1 March	26°F.	5°F.	Brilliant sunshine
2 "	10°F.	-12°F.	Brilliant sunshine

7. Clothing.

No control could be exercised over the clothing variable, especially at Task Force Frigid because, at the time of the tests, the subjects did not have enough garments of the same kind to make up a uniform assembly suitable for the prevailing weather. In general, while on the march the clothing was approximately the same at both Task Forces:

a. Trunk, 3 layers, including ski parka.

b. Feet, 2 to 3 wool socks; shoepacs at Task Force Williwaw; felt or ski shoes at Task Force Frigid.

c. Hands, Wool gloves with leather shell.

With this much clothing one tended to sweat on the march. In the morning and evening when not marching, the men also put on a wool sweater or pile jacket. At Williwaw the men slept in a mountain (single) bag; at Frigid in an Arctic (double) bag. As a rule, only a poncho (Williwaw) or wallboard (Frigid) was between the sleeping bag and the ground.

8. Shelter.

a. Task Force Williwaw. Shelter half-tents (2-man) were used, with no heat. When well secured these tents are satisfactory and were preferred by all of the men over the mountain tent.

b. Task Force Frigid. All test subjects were in a pyramidal tent with a wallboard floor. A coal-burning, pot-bellied stove gave sufficient heat to keep the men comfortable. At ground level it was not so warm and, since the fire eventually went out and the outdoor temperature dropped during the night, the men woke up in a cold environment.

9. Major Activity.

a. Task Force Williwaw. Marching over mountains was the major exertion, though not to the same extent for all of the 4 of the 5 days the men were out. The maximal ascent was 900 feet, and the packs were heavy (60 to 70 pounds).

b. Task Force Frigid. Marching on snowshoes (trail type) on the Tanana River was to have been the major activity. Actually, the first day

had to be spent setting up the bivouac. On the second day the men marched for only 2½ hours because they were not conditioned. On the third day it was necessary to be content with marching without snowshoes for 4 hours on a hard-packed road. On both of the last two days they marched for 4 hours on snowshoes on the Tanana River; i.e., it was necessary to break trail. Each man took his turn breaking trail for 10 minutes, but snowshoeing is hard work even for the last man in the column. The packs were light, as they contained only the noon meal and the three one-man stoves. The men also carried their measuring cups, urine cans, and rifles.

10. Pulse Rate.

a. Task Force Williwaw. It was impractical to measure the pulse rate while marching over the mountains.

b. Task Force Frigid. The radial pulse was palpated and timed with a stop watch. Initial rates were obtained in the standing posture just before setting out on the march. After marching for 50 to 60 minutes, one man was taken out of the column and, during the 1 to 1½ minutes of standing still, his pulse was counted. In the meantime, the other men continued to march in a big circle at the same pace as before, and one by one they were taken out for the pulse count.

11. Test Subjects. Table 7 summarizes physical data about the men. On the average, they were of about the same size in the two tests.

TABLE 7

PHYSICAL DATA ABOUT TEST SUBJECTS

	WILLIWAW	FRIGID
Number of men	12*	11
Age, average range	23** 19 to 33	20*** 19 to 23
Initial weight, average range	158.2 lb. 137 to 183	163.8 lb. 136 to 231
Height, average range	69 inches 65 to 72	70.5 inches 66 to 75.5
Surface area, average range	1.87 sq.m. 1.68 to 2.05	1.92 sq.m. 1.65 to 2.18
Weight/Area, average range	38.52 kgm/sq.m. 36.4 to 41.5	38.53 kgm/sq.m. 34.6 to 48.1

* 10 EM, 2 observers
** 9 EM, 2 observers
*** 10 EM (enlisted men)

C. *Results*

1. *Water Balance*

Table 8 summarizes the budget of water balance. For Task Force Williwaw only the data for the first 4 days that the men were in the field were used because, although they marched on the fifth day, they returned to quarters in the late afternoon and ate and drank that evening. The data for the interval on the fifth day just before reaching the garrison are abnormal in that most men did not bother to eat and drink much in their great haste to get back. One man did not eat or drink anything before the evening mess, and then drank over 2500 cc. (beverages) before going to bed. In both tests the men did not march on one day. Also, in both cases, the men ate breakfast in the mess hall on the first day of the march. Estimates were made of the composition of the recorded items of this meal on the basis of standard nutrition tables, and the results were included in the averages of Table 9. It should be noted that at Task Force Williwaw the general order commanded all men to carry a full canteen of water when starting on the first day. Some men did not comply with this order.

TABLE 8

BUDGET OF WATER BALANCE

Mean Values in Liters per Man per Day

	Williwaw 4 days	Frigid 5 days
Water Intake		
Drink	1.16	1.90
Food	0.75	1.13
Oxidation	0.32	[illegible]
Total Intake	2.23	2.[illegible]
Water Output		
Urine	1.27	[illegible]
Feces	0.10	0.10
Evaporation	1.09	1.54
Total Output	2.45	[illegible].44
Water Balance	-0.22	-0.03
Weight Loss, Kgm.	(-[illegible].28)	-0.025

Table 8 was drawn up in the following manner:

a. Water Intake. All water available for exchange was assumed to have entered the organism by ingestion and by oxidation of only ingested food. This assumption carries the further implicit assumption that the men maintained caloric balance. The water that was drunk was measured by the men. The water in the food was estimated on the basis of recorded food intake and the K Ration composition table. The water of oxidation was calculated as shown in Table 9.

b. Water Output. Urinary volume was measured. Water in the feces was assumed to be 100 cc. The evaporative water loss was calculated by dividing the caloric intake by 2.32 (4 x 0.58 cal/gm water). The assumption that one-quarter of the total heat loss was by evaporation gives a minimal value, because one tended to sweat while marching.

c. Water balance is the difference between total intake and total output.

d. Weight loss at Frigid was obtained by measurement. As explained above, the final weights at Task Force Williwaw were obtained at a time which makes their utilization difficult. By making the gratuitous assumption that half of the total weight loss (2.22 kgm.) occurred on the fifth day prior to weighing, because the men ate and drank little and marched over the mountain, an equivalence between weight loss per day and negative water balance, $\frac{2.22 \text{ kgm}}{2} \div 4$ days, can be obtained.

TABLE 9

FOOD INTAKE

Mean Values per Man per Day

	Grams	Calories*	Water from Oxidation Grams**
Carbohydrate			
Frigid	519	2076	311
Williwaw	307	1228	184
Protein			
Frigid	140	560	56
Williwaw	107	428	43
Fat			
Frigid	108	972	116
Williwaw	90	810	96
Total			
Frigid		3608	483
Williwaw		2466	323

* grams carbohydrate x 4
grams protein x 4
grams fat x 9

**grams carbohydrate x 0.6
grams protein x 0.4
grams fat x 1.07

Attention is called to the following features of Table 8:

a. There was no significant water imbalance in either the Frigid or the Williwaw test. Even when the men are considered individually, the evidence is not conclusive that significant dehydration took place during the few days the men were in the field.

b. Only 40 to 50 per cent of the total water intake was obtained by drinking, 35 to 40 per cent was in the food, and about 15 per cent was produced by oxidation. Thus, although the men drank the same amount in both tests, the total water intake was less at Williwaw than at Frigid by about

one-half liter per day, because the food consumption was much lower at Williwaw. (The mean caloric intake was about 1100 Calories more at Frigid than at Williwaw.)

2. Urinary Output

The data on urinary output are summarized in Table 10. They are of interest because when water intake is reduced the kidneys conserve body water by reducing the volume of urine and increasing the concentration of dissolved substances. On the other hand, the extent to which the urinary volume can be reduced is determined by the limit to which the kidneys can concentrate the urine (Adolph, 1923).

TABLE 10

URINARY OUTPUT AND PROTEIN INTAKE

Mean Values per Man per Day

	WILLIWAW 4 days	FRIGID 5 days
Volume, liters	1.27	1.20
Specific Gravity	1.023	1.027
Total Solids, gm.	72	81
NaCl, gm.	12.0	14.8
Protein Intake, gm.	107	140

Table 8 shows that there was a fair equality, on the average, between the volume of water drunk and the volume of urine excreted. The water supplied by food and oxidation was sufficient to balance the water lost by channels other than the kidneys. Therefore, so long as the food is no more concentrated than E Ration and enough is eaten to maintain caloric balance, men in the Arctic need drink no more than is necessary to form urine of the limiting concentration. It follows that the amount of water that must be drunk is determined principally by the amount of solutes obtained from the diet and from metabolism which must be excreted. (In the desert, water intake is determined largely by the amount of sweat secretion. This discussion for the Arctic holds only for conditions of minimal sweat formation.) In brief, the nature of the diet (high or low in water, salt, and protein) will go far in determining whether or not a man will dehydrate in the Arctic when water is difficult to obtain.

Although the average values of Table 10 for protein intake and urinary constituents are not very high, in individual cases the data suggest that urine of limiting concentration was being excreted, especially in the Frigid test. There were many instances of urinary specific gravity above 1.030; the highest obtained was 1.038. The highest chloride concentration was 296 meq./liter, equivalent to about 17 grams of NaCl per liter of urine, although for all of the men 15 grams per liter appear to have been the limit approached. Large amounts of solutes other than salt were also

excreted (up to 127 grams of total solids per day); the principal item probably was urea. The greatest amount of protein ingested was about 300 grams in one day. The data suggest that about 1 liter of urine must be excreted for every 200 grams of protein ingested.

3. Hemoconcentration.

As explained above, the blood studies at Williwaw were unsuccessful. The results obtained at Frigid are shown in Table 11. It is evident that there was no hemoconcentration during the course of the test. The particular measurements made (specific gravity and hematocrit ratio), of course, do not disprove the possibility that blood dilation was maintained by the transfer of water from the cells to the blood stream. Analyses of blood Na and K might have shed some light but were not made. Because the measurements of water exchange do not indicate any dehydration it is concluded that no transfer of water from cells took place.

It is interesting to note that the values in Table 11 are not out of the range of normal values for men in comfortable environments. In other words, there was no obvious "thickening" of the blood of these men during the months they were in the Arctic.

TABLE 11

BLOOD DATA OBTAINED AT TASK FORCE FRIGID

Mean Values for 11 Men

Day in Bivouac	Blood Sp. Gr.	Plasma Sp. Gr.	Hematocrit Ratio		Hemoglobin gm/100 cc.	Refractive Index Diff. x 10^5
			Calculated	Measured		
1	1.0586	1.0292	43.7	46.5	14.7	1828
3	1.0588	1.0298	43.5	46.8	14.7	1861
5	1.0594	1.0300	44.3	47.5	15.0	1826
7	1.0590	1.0297	43.9	46.7	14.8	1825

4. Pulse Rates

As indicated above, the increment of pulse rate resulting from the performance of standard work was to serve as an objective index of physiological fitness or deterioration. The work was to be marching at a standard pace. At Williwaw, the test was not performed and no pulse rates were obtained. Actually, there seemed to be no evident deterioration for on the last day the men marched back with great alacrity because of the universal desire to get back to quarters. At Frigid, the standard work was marching on snowshoes but the results do not show any evidence of deterioration.

Two factors militated against the usefulness of the test:

a. The men were not conditioned to marching on snowshoes.
b. Many of the men had upper respiratory infection which wore off gradually.

As a consequence of these two factors, the men seemed to show improvement on the last day instead of deterioration (Table 12). Actually, since the men maintained both caloric and water balance and were overcoming their initial state of illness and lack of experience, there is no reason why the pulse rate increments should have been greater on the last day of the test.

TABLE 12

INCREMENT OF PULSE RATE FOR MARCHES AT TASK FORCE FRIGID*

Per Cent of Initial Standing Rate

Mean Values for 11 Men

Hour of March	Day in Bivouac			
	2	3	4	5
1	49.8	15.4	30.6	36.5
2	47.3	24.5	45.3	[illegible]
3		—	[illegible]	—
4		23.5	43.9	37.3
5		34.7	—	49.4
6		36.5	47.5	

* On the 1st day in bivouac the men did not march. On the 2nd, 4th and 5th days they marched on showshoes. On the 3rd day they marched on a hard-packed road. Pulse rates were counted at the end of each hour of march.

III. DISCUSSION

Under the conditions of the observations here reported men did not go into negative water balance. Neither the weather nor the work required of them, however, was beyond their powers using the equipment, food, and supplies furnished. The men also had a lot of time for tending to their water requirements. Nevertheless, on certain days, some men appeared to excrete no more urine than was necessary to eliminate the dissolved substances. Under more severe conditions, some men would very probably allow themselves to dehydrate. Indoctrination might be of no help, for the observers themselves were governed more by the stimuli of the moment than by their knowledge of water balance.

From their personal experience and the data collected, the observers wish to emphasize that cold alone would not solely be responsible for causing dehydration in the field. Many factors would interact in a complicated manner and the net result could be ascertained only by measurement in the field. Some of these factors would be: (1) ambient temperature, (2) wind, (3) equipment for procuring water, (4) time available for procuring water, (5) sweat production, (6) fatigue and exhaustion, (7) amount of water, salt, and protein in the food, (8) terrain, (9) psychological characteristics of the individual and of the group and finally (10) duration of the field exercise.

Each of these factors in turn is general and not particular. Sweat production is determined not only by cold and work, but also by the ventilating properties of the clothing, whether or not it is easier to wear clothing or to carry it on the pack, etc. A stove capable of melting 500 cc. of water from snow in 45 minutes may be leaded up by repeated use. An ax is superior to a heel for breaking through surface ice. Clearly, predictions of water intake based on climatic maps and tables of equipment will at best be but approximations.

IV. SUMMARY

Twelve men at Task Force Williwaw over 4 days, and 11 men at Task Force Frigid over 5 days maintained water balance. Water was obtainable only from natural sources.

The weather and work were not too severe, and the food, equipment, and time for procuring water were adequate enough to make it not too difficult to stay in water balance.

About half of the water intake was from food but, in some cases, the urinary volume although moderately high was only enough to excrete the excess salt and protein metabolites.

The possible importance of the water balance problem in arctic field operations is pointed out.

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FOXHOLE STUDIES

I. INTRODUCTION

A 48-hour foxhole test was planned for both Task Forces but only the one for Task Force Williwaw was performed. At Frigid, foxholes could have been prepared only by blasting procedures. Other factors and considerations also intervened to make it seem advisable not to attempt a test at Frigid.

Some of the fundamental considerations for the Williwaw test were along the following lines. As long as men are supplied with adequate protective equipment they have no particular difficulty enduring a wet-cold environment. This was proved by the 5-day mountain exercise during which the water-balance data were collected and later by the foxhole test performed by the Task Force in February. The observers were interested in studying men, not equipment, and it did not seem profitable to conduct a test which did not submit the men to the rigors of the environment.

During the preceding December field exercise when the troops were in bivouac, a terrific williwaw blew down the tents and the men abandoned their equipment and retreated to the base camp. What would have happened physiologically to the men, if the enemy had intercepted their retreat and forced them to dig in without their protective gear? In the January mountain exercise, the men broke column on the return march and went into firing positions. Before doing so, however, all dropped their heavy packs and left them behind. If the exigencies of combat had then called for a sudden advance down into the valley with subsequent interruption of the supply line, how well could they have endured protracted exposure without the benefit of extra personal equipment? The tundra of the North is barren of trees, farmhouses, barns, etc., which could be adapted to one's needs, and it is not inconceivable that in combat over the wastelands men could be cut off from their supplies and equipment for a significant period of time.

Having learned by observation over a period of 10 days in the field that the test subjects suffered no undue strain in the wet and windy cold environment of Adak, it seemed worthwhile to the observers to test the potentialities of these same men when certain standard items of equipment were withheld. Foxholes provided both logical and convenient devices for holding the men relatively immobile in the wet-cold environment.

II. EXPERIMENTAL

A. Objectives

The general objective was to ascertain the physiological strains which are induced by protracted exposure in a wet-cold environment. To this end, the following physiological observations and measurements were made: (1) skin and rectal temperatures, (2) heart rate, (3) kidney function, (4) water and food intake, (5) fatigue and the ability to rest and recover and (6) subjective reactions.

B. *Materials and Methods*

The test was performed on a plateau of Mount Moffett on Adak Island on 26 January 1947.

The subjects were 8 enlisted men and 1 first lieutenant of an infantry company. Their clothing was the same as that worn in the water-balance study previously described. They were also permitted to put on wet-weather parkas and trousers, but were prohibited the use of foxhole covers, sleeping bags, and accessory heat except canned heat issued to warm the E Rations. They were all well rested, fed, and warm before starting the test; no one was suffering the after-effects of alcoholic intoxication. Food was given every 6 hours, but water was dispensed in measured quantities as part of the diuresis tests. Candy bars and cigarettes were freely available, but were infrequently requested.

Preliminary measurements, including nude and clothed weights, pulse rate, and body temperatures were made in a warm hut near the foxholes. The temperatures were measured in the same manner as in the Eskimo studies. As soon as these preliminary procedures were completed on a man, he went out and entered his foxhole but, inasmuch as it took about 3½ hours to complete the procedures on the 9 men, they did not start their exposures simultaneously. Two men were in each of 4 foxholes, but the officer was in the fifth foxhole by himself. They were under strict orders to remain in their foxholes for 48 hours, unless the observers found undue strains arising and called them out individually.

C. Results

1. Weather. Measurements of air temperature and wind velocity (with a totalizing anemometer) were made every 10 minutes until about 0030 hours. During this time the air temperature at 3 feet above the ground was 28°F. to 34°F., and at the bottom of the foxholes it was about 30°F. to 32°F. The wind velocity averaged about 30 miles per hour until midnight, when it rapidly increased. The average velocity for the last 10-minute period for which a measurement was made was 72 mph. (which means that at times it was even higher). The men in the foxholes, however, claimed that the wind had negligible cooling effect, although it was annoying because of the dirt and snow it blew into their faces and food. The sky was always completely overcast, and at about 1700 hours (about 8 hours after the exposures started) snow began to fall. At the time the test was terminated, about 10½ hours later, the foxholes were half filled with snow.

The above figures give an inadequate description of the weather, and it is therefore difficult for one sitting in a comfortable chair to appreciate the full fury of the storm which descended upon the test. The roaring and blinding wind and snow restricted vision to a few feet and made verbal communication nearly impossible. Useful observations could not be made until the storm had abated. In the meantime, all that the observers and their assistants (a sergeant and a corporal) could do was make periodic visits to the foxholes and attempt to encourage the men to carry on.

2. *Endurance.* *Five men were unable to endure these conditions for more than an average of 16 hours (15.4 to 17.4 hours). They left their foxholes individually (in 3 cases without knowledge that anyone else had done so)* and retreated to the hut, which they must have entered not without some hesitation for they did not know what reprimand awaited them. They all looked very wet, but they were not asked to strip to be weighed because the hut was cold. (The wind had blown snow into the heater, which was outdoors, and had stopped it at about midnight.) Thus no measure of the amount of moisture in the clothing was obtained. The outer garments were removed, and the men wrapped themselves in blankets and just sat and shivered until they were taken back to quarters. They all drank hot coffee and some ate candy bars.

When the fifth man abandoned his foxhole at 0330 hours, the observers decided to terminate the test and they called in the remaining 4 men. These had stayed out an average of 16 hours. In the subsequent interrogation, made individually a day later, they estimated their further endurance as follows: 4 more hours for 1 man, 12 more for 2 men, and the full 48 hours for 1 man. Adding these estimated additional hours to the 16 hours the men had actually stayed in the foxholes, one obtains the following distribution of probable endurance times for the whole group: 6 men could endure only 15 to 20 hours; 2 men could endure about 30 hours; only one man thought he could last 48 hours. The notable feature of this distribution is that it is skewed to the range of short endurance.

It is worthwhile at this juncture to reexamine the environmental conditions which caused the men to stay in their foxholes for 16 hours and then to leave them in a hurry. The stimuli can be classified in 2 groups: those which inhibited flight and those which stimulated flight from the foxholes. In general terms they were as follows:

a. Stimuli which inhibited flight:

(1) The military order to stay in the foxhole until told to get out.

(2) Social stimuli which encourage one to "take it" and discourage yielding to unpleasantness.

(3) The knowledge that the test would not last forever, and that the observers would terminate it before deleterious effects supervened.

(4) Minor stimuli such as those of personal relationship between observers and subjects, interest in helping science, etc.

b. Stimuli which excited flight:

(1) Persistent cold.

(2) Wetness, which was disliked independently of its cooling effects.

(3) Stiffness from uncomfortable posture.

(4) *Wind noise.*

(5) Proximity of the hut, presumably warm though actually it was not after midnight. Only one subject admitted the force of this stimulus; one was uncertain on the matter and 3 would have left their foxholes even in its absence.

(6) The probability that disobedience would not meet with severe censure. One subject was not asked about this matter and no entry was made as to another's response. Three men said only positive foreknowledge of a severe court-martial penalty would have forced them to stay in longer.

These two antagonistic sets of stimuli were acting continuously. At first the inhibiting set was prepotent, but gradually over 15 hours the second set summated and suddenly caused flight. Undoubtedly, "fatigue" had something to do with lowering the threshold to the excitatory stimuli. How powerful this summation finally became may be gauged by the assertion of 4 men that even enemy fire would not have been an adequate stimulus to inhibit flight. As one subject put it, "All right, you'd be shot and dead and gone. You wouldn't have frozen feet no more."

In further discussion the 5 men who abandoned their foxholes will be referred to as Group 1; the 4 men who stayed in the foxholes will be called Group 2. The data will be considered to see if they shed any light on why Group 1 reached the limit of endurance and Group 2 did not. Since all observations were stopped about 1 to 3 hours before the men left their foxholes, the data do not give information about the final critical moments. Nevertheless the data for the first 14 hours are instructive.

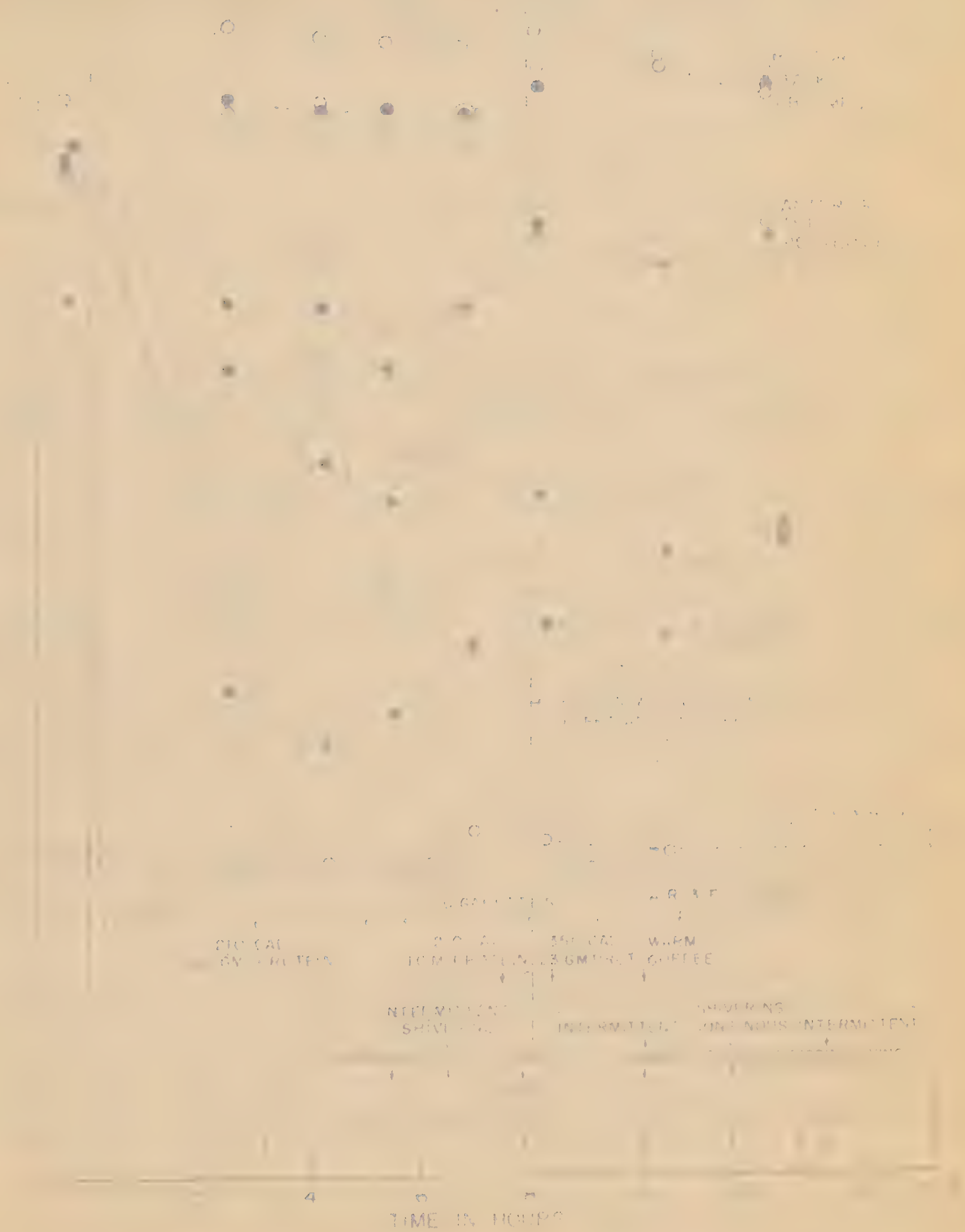
3. Body Temperatures. The first conjecture that comes to mind as to why Group 1 left their foxholes is that they did not maintain their body temperatures as high as the men in Group 2 did. As an example of the results obtained, the measurements on subject 13 are shown in Figure 2. They are particularly interesting because this man stayed in his foxhole for the shortest length of time (15.4 hours). Attention is called to the following notable features:

a. The temperatures of the trunk were maintained at a high level. The skin over the back and abdomen warmed up after the wet-weather clothing was put on, but the rectum showed signs of slight cooling during the last two hours of measurement.

b. The thigh skin cooled upon exposure but remained between 72° to 77°F. and warmed up to about 84°F. after the wet-weather clothing (parka and trousers) was put on.

c. The coldest part of the body was the exposed cheek.

d. The foot (in 3 pairs of socks and shoepacs) cooled slowly over five hours and leveled off at around 60°F.



2 BODY TEMPERATU...

e. The temperatures of the finger and toe oscillated; unfortunately, the finger couple broke early in the test. The toe warmed and cooled between 50° to 70°F., with 60°F. as an approximate mean. This periodic fluctuation in the temperatures of the extremities shows no obvious correlation with food intake, activity, or smoking. Miller (1943) obtained similar temperature rhythms of the digits in cold room experiments (-40°) lasting up to 8 hours; he offered no explanation in his brief report.

As compared with the results in Figure 2 for subject 13, the other 8 men showed the following general picture:

a. All maintained high trunk temperatures.

b. The cheek was usually not the coldest part of the body.

c. The finger and toe showed only one or two oscillations.

d. The extremities cooled to the following levels: in Group 1, two men averaged around 60°F., and three around 55°F.; in Group 2, two averaged around 60°F. and two around 55°F.

Thus, the evidence does not permit a differentiation between the two groups on the basis of body temperatures.

4. Subjective Reactions. Even though all of the men showed approximately the same general temperature responses during their exposure, it is possible that the men of Group 1 felt subjectively colder than those of Group 2. Each time the pulse was counted the subject was asked how he felt on the following parts of the body: toes, feet, knees, fingers, hands, and face. The subject answered in one of the following terms for each part: cool, cold, painful, or numb. If he did not feel even cool, it was assumed that he felt comfortable in that part of the body.

To an overwhelming extent the men were uncomfortable mostly in their toes, at least during the time that the data were collected. This is surprising because the toe, finger and cheek temperatures were usually at the same level. The data for the toes are given in Table 13.

If a report of cold, painful or numb is considered as very uncomfortable, then the men of Group 1 averaged very uncomfortable in their toes 7 out of the possible 10 times that they could report their feelings. Group 2 averaged great discomfort 4 out of the possible 10 times. Thus, on the average, those who left their foxholes felt colder in their toes than those who stayed in to the end of the test, although there was a slight overlap between the two groups.

As to the other parts of the body, for a total of 60 possible reports (10 times for each of 6 parts of the body) Group 1 reported very uncomfortable for an average of 14 times (10, 11, 14, 16, and 19); Group 2 averaged 6 reports of very uncomfortable (1, 1, 10, and 11). These averages appear to be low; unfortunately, the notations were stopped 1 to 3 hours before the end of the test. Naturally, the men of Group 1 claimed that in this time they became very cold; at any rate, they were too cold to sleep. The general conclusion is that Group 1 felt colder, or reported they felt colder, than Group 2. Subjective reporting does not correlate with temperature measurements. (See Fig. 2.)

TABLE 13

SUBJECTIVE REACTIONS FOR TOES

Hour of Exposure	SUBJECT NUMBER								
	2*	3*	4	5	6*	7*	8	9	11*
0 - 1	—	—		—	—	—			--
1 - 2	Cold	Cold					Cold		—
2 - 3	Cold	Cold		Cold	Cold		Cool		Cold
3 - 4	Cold	Cold		Cool	Cold	Cold	—		Cold
4 - 5	—	Cold	—	Painful	Painful	Cold	Cold		Cold
5 - 6	Cold	Cool		Painful	Cold	Cold	Cold	Cool	Cold
6 - 7	Cold	—		Cold		Cold	Cold	—	Painful
7 - 8	Cold		—	—	—	—	—	—	Painful
8 - 9	—	—	Cool .	—	—	—		Cool	—
9 - 10			—		Cold	Cold	—	Cool	—
10 - 11	—				Cold	Cold	Cold	Cool	Numb
11 - 12		Cold			Cool	Cool	Cold	Cold	Numb
12 - 13	Cold	Cold	Cold	Cool	Cool	Cool	Cold	—	Cold
13 - 14	Painful	—	—	—	—	—	—	—	Cold

Blank spaces, comfortable
—, no record
* Abandoned foxholes

5. *Activity.* *Since the clothing and environment were approximately the same for all of the men, the fact that their several body temperatures were similar indicates that they all were producing by oxidation about the* same amount of heat. It is interesting to note whether or not the two groups can be differentiated as to the predominant mode of heat production--shivering or coordinated muscular activity. Activity ranged from digging to sleeping. Digging consisted of deepening the foxhole or excavating a lateral tunnel. On occasion, the men stood up and moved around for the sake of "taking the stiffness out of their joints"; in other words, cold was not the sole stimulus for increasing heat production.

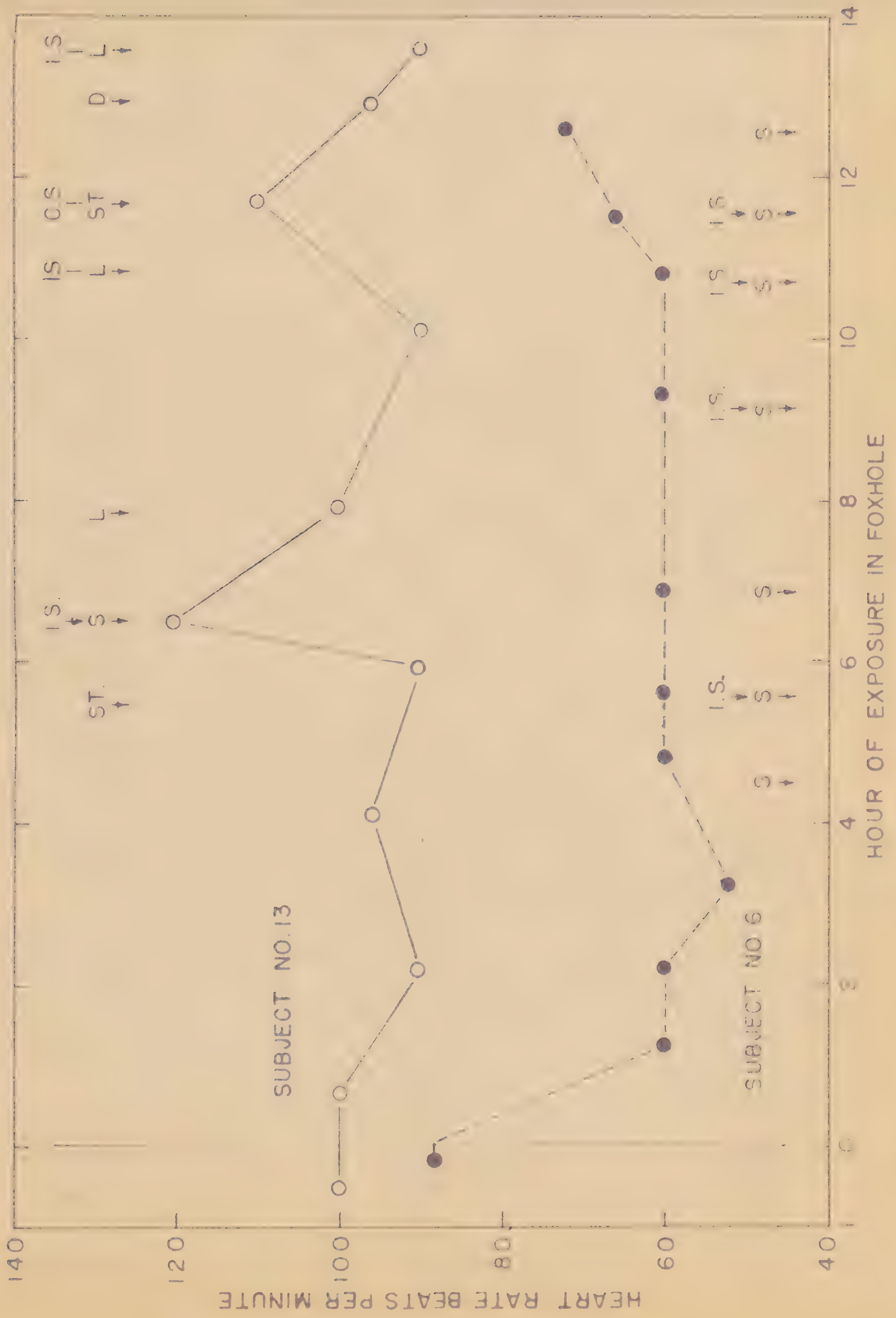
Notations on shivering and activity were made 7 times, about once per hour, starting after about 5 hours of exposure. If intermittent shivering is scored as 1 and continuous shivering as 2, then the observed shivering averages 3.2 for Group 1 and 0.75 for Group 2. Thus, Group 1 shivered about 3 times as much as Group 2, roughly speaking. The observed activity was scored as follows: lying, 1; sitting, 2; standing, 3; digging, 5. Group 1 had an average activity score of 17 (14 to 20); Group 2 averaged 25 (21 to 28). Thus, by the evidence obtained, Group 2 was about 50% more active than Group 1.

The above data on shivering and activity are indeed rough and fragmentary, but they were obtained without conscious bias for the observers had no premonition that certain men would quit and others would not or that the test would terminate so abruptly. For this reason, it would seem that more than chance or bias was operating to give the above indications that Group 1 produced extra heat more by shivering than Group 2 did, whereas, the latter were more active than Group 1.

As to fatigue, no quantitative evidence was obtained to differentiate the two groups. Naturally, as the night wore on, all men became very tired. How can fatigue be measured, especially in foxholes during a storm? Analyses for adrenocortical steroids in the urine might have given some information. It is significant to note, however, that the limit of endurance was reached at that time of the diurnal cycle when one usually tends to feel tired and weak, and not at an earlier or later time.

Only one man was able to sleep; he was in Group 2. At 0130 hours he curled up in his tunnel and slept until ordered out at 0530 hours. It is probably significant that he was the only one who ate his midnight ration, which included 690 Calories, 24 grams of protein, and 500 cc. of warm coffee. Two more men tried to sleep after midnight, but could not continue beyond about 30 minutes because the cold woke them. The remaining six men felt too cold even to try to sleep. Thus it cannot be said that the men of Group 2 had greater endurance than those of Group 1 because the former were able to restore the physiological mechanism by sleeping.

6. Heart Rate. Figure 3 shows the pulse rates for the subject with the highest, and for the subject with the lowest counts, both in Group 1. All other subjects had heart rates intermediate between these two extremes; the average for the 9 men was about 80 beats per minute. The highest count obtained was 126, and the lowest was 52, each only once (Fig. 3). The results do not indicate cardiac strain or violent shivering, which has been found to be correlated with acceleration of the heart in nude men (Adolph and Molnar, 1946). No correlation was found between heart rate and endurance.


HEART RATE BEATS PER MINUTE
HOUR OF EXPOSURE IN FOXHOLE
SUBJECT NO. 13
SUBJECT NO. 6
140
120
100
80
60
40
0
2
4
6
8
10
12
14

7. *Kidney Function. The details of all of the kidney function tests (simple water or coffee diuresis) performed on Adak will be described in a separate report. Some of the results are shown in Figure 4. They* suggest that initially upon exposure to cold there is a rapid diuresis even when no fluid is ingested. After more than three hours of exposure, however, there is no diuresis unless fluid is ingested and the diuretic response to 500 cc. of water is not great. Similar results were obtained with coffee. It would have been difficult to force the subjects to drink more than 500 cc. in the cold. No correlation could be found between the diuretic response and endurance. Despite the low response to 500 cc. of fluid, however, the total output for the day by the kidneys was adequate, as will be shown below.

8. Water and Caloric Intake. The mean values for fluid and caloric intakes and urinary outputs are summarized in Table 14. The data were collected over a period of about 22 hours, of which about 16 were spent in the foxholes. The men of Group 2 ate more food than those of Group 1, as can be seen from both the number of calories ingested and the amount of water in the food. Group 2 ingested about 1100 Calories more than Group 1, on the average, although one man in Group 1 ate about the same number of Calories (3010) as on the preceding days. The amount of fluid drunk while in the foxholes was the same for both groups since it was dispensed in measured quantities. There was no significant difference between the two groups as to urinary volume, specific gravity, or total solids. Water balance was maintained by all and the kidneys apparently excreted both water and solids normally during the exposure.

TABLE 14

WATER AND CALORIC INTAKE AND URINARY OUTPUT
IN FOXHOLE TEST

Mean Values for about 22 Hours

	GROUP 1 Abandoned Foxholes	GROUP 2 Ordered out of Foxholes
Number of Men	5	4
Time in Foxholes	16.07 hours (15.42 to 17.42 hours)	16.15 hours (15.58 to 16.50 hours)
Caloric Intake	2445 (2170 to 3010)	3530 (3160 to 3930)
Water Intake Drink Food Oxidation*	 1.47 liters 0.80 0.31	 2.03 liters 1.07 0.47
Total Intake	2.58 liters	3.57 liters
Urinary Output Volume Sp. Gr. Total Solids	 1.37 liters 1.020 67 gm	 1.51 liters 1.020 78 gm

* Calculated on the basis of ingested food.

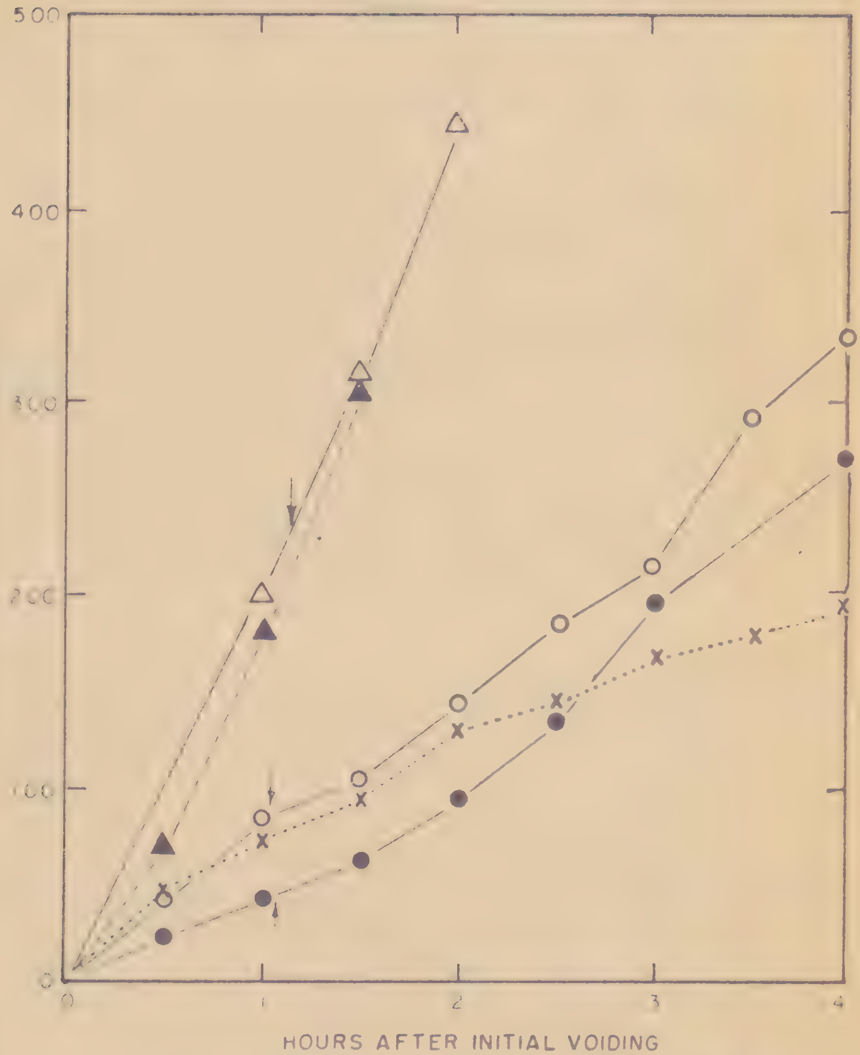


FIG. 4. RESULTS OF WATER DIURESIS TESTS

○ = Mean for 3 subjects who drank water; initial voiding 3 hours after entering foxholes.

● = Mean for 3 subjects who drank water; initial voiding 9 hours after entering foxholes.

x = Non-drinker; initial voiding 5 hours after entering foxhole.

△ = Mean of interpolated values from curves of earlier test on drinkers sitting outdoors. Exposure at 0 time.

▲ = Mean of interpolated values from curves of earlier test on non-drinkers sitting outdoors. Exposure at 0 time.

Ingestion of water at time indicated by arrows.

9. Emotional States. It is generally considered that the mechanisms of the body which give rise to some of the emotional responses have had, during the course of evolution, survival value by putting the organism in instant readiness to cope with emergencies. Since during the terminal hours of the test an emergency situation existed by all the usual standards, it is interesting to inquire how the two groups of men responded emotionally. Heightened activity of the emergency mechanism of the body produces certain characteristic responses. Those for which some information was obtained were as follows:

a. Hunger. It is notable that 4 of the 5 men in Group 1 had reduced food intakes during the course of the day. The plausible inference is that their stomach contractions were partially inhibited by heightened sympathetic discharges. By midnight, however, 3 of the men in Group 2 also were not hungry, for only 1 of them ate his ration at that time. It is clear that hunger was not a stimulus which caused flight; instead, the absence of hunger indicates that the emergency mechanism was in operation, and more so in Group 1 because they ate less during the day.

b. Anger. Some evidence was obtained indicating that 4 men in Group 1 were angry at their plight; the fifth was probably not. In Group 2, 3 men were not angry and the fourth was probably not. It follows that the emergency mechanism was probably more active in Group 1 than in Group 2.

c. Sleep. Sleep involves general relaxation and perhaps inhibition of certain parts of the hypothalamus; in other words, during sleep the emergency mechanism must be at a low ebb. Only 1 man (in Group 2) was able to sleep; hence, the two groups cannot be differentiated on the basis of tenseness.

The data on emotional states are clearly inadequate, but they are presented to emphasize the importance of psychophysiological aspects which are generally not properly studied. As a rule, a physiologist investigates that which he can readily measure, e.g., the pulse, skin temperature, urine, etc. Yet the factors which determine performance and endurance may be of a more subtle nature than heat balance, water balance, etc. Clearly, the relatively unexplored field of psychophysiology requires development. Perhaps the first approach should be the adaptation of present physiological techniques to the subtler problems. For example, although knowledge of body temperatures is important, it is perhaps more important to know about frequencies of digital vasodilatations which could be deduced from more frequent temperature measurements.

10. Miscellaneous Information.

a. Physical data. There was no significant difference between the two groups as to: (1) age--average for Group 1, 23; for Group 2, 21; (2) weight--average for Group 1, 152 lb.; for Group 2, 154 lb. There was no extraordinarily large man in the test; the heaviest was 168 lb. (in Group 2); (3) height--average for Group 1, 68.5 inches; for Group 2, 67.8 inches.

b. Intelligence and education. Unfortunately, the AGCT scores were not obtained. The observers guessed that the men had about average intelligence. Excepting the officer, the two groups had about an even amount of schooling.

c. *Origins.* The men in Group 1 were born in Arizona, Oklahoma, Texas, West Virginia and New Jersey. Those in Group 2 were born in Tennessee, California, Colorado and West Virginia. Thus none of the subjects were born in the northern states; on the other hand, complete life histories were not obtained and it is possible that some of the men were reared in the northern states.

d. Previous experience. All of the men had arrived on Adak 5 months before the test and had taken part in the Task Force's field exercises. They thus had an equal opportunity to become acclimatized to the conditions of Adak.

Four of the 5 men in Group 1 had been in combat (ETO) for 3 to 12 months. In Group 2, one man had been 4 months in combat (ETO), 2 had not, and no entry was made for the fourth man. It appears that those with more combat experience had less endurance than those with little or no combat experience. The subject with the shortest endurance but the longest combat experience (12 months) had this to say, "The experiment conducted on Adak, 26-27 January 1947 was, in my opinion, one of my most harrowing experiences. I have been in worse positions, been colder, and have been wetter, but very few times. This experiment compares favorably with some of my most miserable experiences, minus the threat of the enemy."

III. DISCUSSION

The chief result of this study is that of the 9 men who successfully carried through for 5 continuous days in the field, 5 men were unable to endure similar conditions for more than 16 hours when movement was restricted and certain protective items were withheld. Their endurance seemed to be limited not strictly by physiological factors (thermal balance, cardiac strain, kidney function, etc.) but by psychophysiological factors (heightened activity of the emergency mechanism). The probable practical military implications are that in environments similar to that on Adak: (1) The men should be relieved every 12 to 16 hours, or (2) measures should be taken in time to insure that all men have their protective gear, or (3) men should be preselected for their endurance, or (4) endurance should be prolonged by methods yet to be worked out.

The following criticisms can be directed at the test:

1. There were too few subjects to permit generalization. It seemed more important to the observers to study a few men intensively than to squander their efforts superficially over a host of men. The object was not to prove the universality of a generalization, but to discover significant physiological strains even if they occurred only in individual cases. It must also be realized that a careful field study requires incomparably more work than a laboratory test.

2. Older and more experienced officers could have held the subjects to their duties for a longer time than the observers succeeded in doing. The observers entertain no delusions about their ability to command. On the other hand, the observers do maintain that they did secure the full cooperation of the men during the preceding 10 days in the field and that the men broke only when the situation became extraordinarily severe. Furthermore, a soldier is trained to be a soldier and not a test subject; the observers, therefore, had to supplement military procedures in order to

attain their end. Finally, from personal conversations, the observers gathered that when the infantry found itself in a situation comparable to the foxhole test, namely, when the December williwaw blew down the tents and exposed the men in the early hours of the morning, the responses of the men were such that the field exercise was terminated. These men were not in charge of observers. The great difficulty in controlling men in a blinding windstorm is that of verbal communication.

3. A soldier always sees to it that he is as comfortably ensconced as possible and, therefore, the test conditions were unrealistic. This generalization must be based on experience in environments which can supply something, if only boughs, straw or farmers' blankets. A desolate wasteland, however, is completely barren. Moreover, in the test all of the men could have made themselves more comfortable by digging lateral tunnels. Four of the subjects (2 in each group), however, did not even attempt this, and the 5 men who did excavate could have made far more comfortable tunnels. The results of the test do not bear out the contention that a soldier always makes himself comfortable.

4. The subjects should have been offered some distraction, such as cards or ammunition to fire. Cards were not prohibited, but it would have been impossible to play cards in the dark and in the snow. Firing was out of question, but do soldiers always fire ammunition for amusement when they are biding their time in foxholes? Finally, one subject expressed his annoyance at the chief distraction of the day--the frequent visits of the observers or the assistants. He just wanted to sit and not be bothered.

5. Combat is such a frightening experience that it can keep men in foxholes even under the severest environmental conditions. This possibility is real but cannot be tested in peacetime. Most accounts of war experiences tend to become anecdotes, and often do not give accurate information to the critical mind. Finally, in this particular test the men with combat experience tended to make a poorer showing than those without it; in fact, the subject who had had the most exposure to combat found the test one of the worst ordeals of his life.

IV. CONCLUSIONS

1. Men in a wet-cold environment are not under as severe stress as men in a dry-cold environment. Wet-cold, however, does impose limitations on endurance but not by direct and immediate action, such as rapid cooling and freezing, but by indirect influence over a period of hours. Many stimuli, e.g., wetness of fingers, unimportant in comfortable environments, summate with the passage of time and elicit overt responses which indicate the limit of endurance. Psychophysiological factors play a more prominent role than purely physiological factors. The temperatures of even the extremities do not approach freezing but their discomfort summates with other factors to limit endurance.

2. Preselection of men for duty in wet-cold environments should be based on factors which correlate with endurance. The results of this study suggest that men who report that they feel cold, shiver more than move around, have inhibited appetites in the cold and are easily provoked to anger are poor risks.

C. Measures for prolonging endurance should be directed at the factors which summate their influence and thus bring endurance to a halt. The value of other expedients, e.g., food, drugs, hormones, etc., should be explored.

D. Protective items (clothing, heating devices, etc.) are very practical measures but they do not increase one's innate endurance. They serve by walling off the man from the unbearable environment. When they are not available, the brunt of the stress bears down upon him.

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1. Man has not yet conquered the cold North in the manner of the polar bear. He has merely inserted little pockets of heat from which he occasionally sallies forth. Even the Eskimos do not live continuously in the cold. These obvious statements carry a practical implication sometimes overlooked. If there is such a thing as physiological acclimatization to cold, it occurs in the natural world as a result of intermittent exposure. Continuous exposure may or may not hasten the process, but laboratory experiments designed to study it are more realistic, if they utilize intermittent exposures.

2. Merely to carry on ordinary living in the North requires a lot of work; any further accomplishment involves an extraordinary expenditure of effort. It follows that manpower demands are high.

a. The commanding officer of Task Force Frigid stated that he thought the unit of operation should be, not the individual, nor even a pair of men, but 5 or 6 men. They would, of course, assist each other in moving individual equipment, making and breaking camp, etc., but equally important, they would reduce the element of fear, especially of becoming a lost casualty. The group would perform the task ordinarily assigned to one or two men.

b. It is evident that these ideas of operation are more comprehensive in scope than those which consider merely the decrement in efficiency due to cold alone. Man's overall efficiency in the field is reduced, not merely because of the cold, but also because of all the additional things which have to be done because of the cold. Time is lost packing and transporting extra personal gear; wiping one's nose; trying to find an object dropped in the snow; scraping the snow away to mount something; watching one's step to avoid slipping and breaking (and perhaps freezing) a limb; dancing around to warm up, etc. None of these activities reduce the dexterity of a particular manipulation, but they probably go further in reducing the total useful accomplishment in unit time than decrement in dexterity.

While watching men operate in the field, it is difficult for an observer to avoid the conclusion that laboratory psychomotor tests have but little bearing on the problem of calculating manpower needs. The laboratory tests are necessary for laboratory purposes—e.g., for determining the best location of a knob on an instrument panel. For field problems, however, it is best to set up field experiments.

c. The difficulties and extraordinary work involved in conducting field observations on men are apparently not sufficiently appreciated. It is particularly important that the chief observer should not be forced to restrict his attention to a single series of measurements but should be free to oversee all aspects of the test.

3. Without a doubt, it is essential to supply men with hot food in the Arctic but if the Army is not going to operate beyond field kitchens, its range of activities will be limited. One is especially convinced of this possibility when looking down upon such a place as the Brooks Range

from an airplane. The development of a good Arctic field ration seems to be indicated. The present E Ration does not fill the bill, nor would a survivor's ration of a limited number of calories be adequate. A good Arctic field ration should be high in calories, high in water and moderately low in ingredients (proteins and salts) which raise the urinary volume. It should, of course, be acceptable. It is possible that one can eventually learn to subsist on a diet of caribou, or something, but during the learning period difficulties will develop and by the end of the period one may be back at a kitchen. After a few days on E Ration, most men restrict their choices to a limited number of items, and these acquire a uniform taste. Many men also complained that there was nothing to chew on in the meat ration; it was nothing but a homogeneous soft mixture.

The following suggestions are offered for consideration:

a. The bulk of the calories should be in foods like cookies and crackers, which can be nibbled at frequent intervals without need for heating. They should have enough binding to prevent cracking and crumbling. The present fudge candy is too hard to bite, unless first warmed against the body for several hours.

b. Water should be supplied, as in the E Ration, in the meat and fruit. The meat should be in the form of chunks, larger than dice, and associated with discrete chunks of carbohydrate (potatoes, macaroni, etc.). The cans should be rectangular in shape, like a sardine can, and perhaps bisected by a partition with meat in one-half and potatoes in the other.

c. The gasoline stoves should be more easily ignited than the present one-man stove, and should lose less heat to the environment. The food can could be placed in an insulated well with a cover. It should be possible to eat directly from the stove.

d. A large can-opener and spoon should be part of the individual equipment. All packages should be easily opened with mittened or, at least, gloved hands.

4. The behavior of the gastro-intestinal tract in the field ought to be studied. Appetite, inhibition of hunger, ability to drink cold water, constipation and impaction, flatulence and "heart-burns," etc., may all influence performance to a greater degree than cold per se. No doubt, explorers, trappers, Eskimos, etc., are able to carry on without all these investigations. They form a group, however, who have been screened by natural selection. We are concerned with the performance and well-being of a heterogeneous group of men who are removed from a comfortable environment, where they had developed very fixed habits, and are thrust into the Arctic.

5. Perhaps one of the most important problems of the Medical Department is the cause of death in hypothermia. Significant reduction of deep body temperature does not occur with active men. It would, however, take place with exhausted or wounded men, unless help was quick in coming. Man dies long before he freezes. If he could take something that would counteract the causes of death and keep him alive until he did cool to 32°F. (instead of just 75° to 85°F.), many lives could be saved.

Body cooling is accelerated even on Adak, where the air temperature is not low, but the ground is wet and the wind velocity high. Indeed, the "wind-chill" may be as great there as anywhere. Many parts of the Arctic during spring and autumn have weather like that on Adak. Moreover, when the temperature is above freezing there are many pools of water. Immersion hypothermia occurs rapidly (Molnar, 1946), and is as much a problem for the Army as for the Navy.

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OBSERVATIONS ON PHYSIOLOGICAL PROBLEMS IN DESERT HEAT

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1 April 1948

ABSTRACT

OBSERVATIONS ON PHYSIOLOGICAL PROBLEMS IN DESERT HEAT
TASK FORCE FURNACE, YUMA, ARIZONA

OBJECT

Scientists and technicians from this laboratory accompanied Task Force Furnace on the Arizona desert in July 1947, to study the influence of environment and activities on the military personnel.

RESULTS

Measurements indicated that an average of about 6 liters of sweat was produced daily by tank crew men and others working under the conditions encountered at Furnace. The amount of water drunk in satisfying thirst was found to be the minimum necessary to maintain water balance. This was shown by the uniformly scanty but concentrated urinary output, and the fact that pitressin produced but little alteration in urine excretion. The ready availability of loose salt and salt tablets served to prevent any serious incidence of salt depletion among the personnel.

Tests of chemical protective clothing by others were observed and the potential dangers of the impermeable suit were pointed out.

CONCLUSIONS

No situations were found at Furnace where the reactions of the men to work in the desert opened up new problems of physiological or medical importance requiring immediate and intensive study.

RECOMMENDATIONS

None.

Submitted by:
P. J. Talso, Capt., M.C.
R. W. Clarke, Ph.D., Physiologist

Approved Ray G. Daggs
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Director of Research

Approved
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Lt. Col., M.C.
Commanding

GENERAL PLAN

I. INTRODUCTION

An invitation was extended by AGF Board No. 2 to the Medical Department Field Research Laboratory to send scientists, observers, and technicians to Task Force Furnace near Yuma, Arizona, to study desert problems, to advise Board No. 2 in regard to efficiency and comfort of personnel in armored vehicles and in other situations in desert heat, and to conduct any other investigations under the broad scientific aims of the laboratory that were feasible under the prevailing conditions.

AGF Board No. 2 was "assigned the mission of establishing, commanding and operating the test detachment to be known as Task Force Furnace in the vicinity of Yuma, Arizona, ..." during the summer of 1947 (1). In an undated 'General Plan of Test, etc.' (2) issued by the Chief Test Officer of Board No. 2, references were made to reports from the Armored Medical Research Laboratory which had a direct bearing upon the desert tests to be carried out.

The following problems were studied:

1. Observations were made concerning the physiological environment in vehicles to determine the stresses placed on tank crews when it was not feasible to measure on the men themselves the effects of the environment.

2. Physiological observations were made on tank crews to ascertain the changes in pulse rate, fluid intake and output, concentration of the urine, and to note the deviations from normal as a result of the unusual desert conditions.

3. Experiments on additional human subjects (technical observers), included determinations of water balance, diuretic and antidiuretic responses, and urine concentration.

4. Miscellaneous observations were made on various aspects of life in the desert, including the use of evaporative coolers and protective clothing.

II. METHODS AND PROCEDURES

A. Personnel

Two officers, 3 enlisted men, and 1 civilian scientist were sent from M.D.F.R.L. The persons and dates follow:

J. H. St. John, Capt., M.C.	16 June - 20 July
R. C. Pickens, Tech. 4	16 June - 5 August
L. L. Rodgers, Tech. 3	16 June - 5 August
P. J. Talso, Capt., M.C.	1 July - 5 August
F. J. Urbush, T/Sgt.	1 July - 5 August
L. T. Clarke, Ph.D., Physiologist	1 July - 1 August

B. Location

The general test area was located near the southeast corner of the wartime desert training center, shown in Figure 1. A Base Camp was established at the site of an abandoned air strip where a 5,000 foot runway was available for use by aircraft and where the various paved taxi strips served as interior roadways for camp traffic. The camp was located about 17 air miles (25 by road) northeast of Yuma, Arizona, and about 9 miles by desert road from Engineer Board Yuma Test Branch at Imperial Dam on the Colorado River. The base camp was laid out as shown in Figure 2.* Water was pumped from an irrigation canal at the Colorado River to the treatment unit at the camp.

The enlisted men were quartered in pyramidal tents, and the officers in wall tents with two flies. Except at a few times when storms threatened, the walls were rolled up and ample ventilation was present.

Three tank-driving courses were laid out and marked. Gila and Silver courses west and northwest of the camp offered the roughest terrain while Castle Dome course, on the east side of Arizona Highway 95, was a 10-mile loop combining the terrain features of deep sand and gravel with moderately rough spots interspersed. Figure 3* indicates the roughness and dustiness typical of the Gila and Silver courses and portions of Castle Dome course.

The Medical Department Field Research Laboratory truck (Fig.4*) was set up at a point about 800 yards east of the Task Force headquarters (Fig. 2). This somewhat isolated spot was chosen principally in order to assure quiet for the audiometric tests which Captain St. John did as a part of his Fort Knox project, reported elsewhere (3). The site had the further advantage of permitting the use of electric power from a portable generator without disturbing other units when the camp plant was not operating.

C. Weather Data

The test site is one characterized by very low rainfall, high temperatures, extremely low humidity, and moderate winds. The average annual rainfall is less than 4 inches (4), and therefore desert conditions prevail. At Yuma, the average July temperature is 91°F. with a maximum of about 120°F., and the July rainfall is negligible, a 24-year average being 0.22 inch (5). The July skies are generally quite free of clouds and this factor, together with the low humidity, produces a high intensity of solar radiation at ground level.

A weather detachment from Tinker Field, Oklahoma, was assigned to Furnace, and a transcript of their detailed observations was supplied to Medical Department Field Research Laboratory by Board No. 2. Summaries of these data are found in Table 1, page 7.

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* Photos, Fort Knox Signal Corps Photographic Section

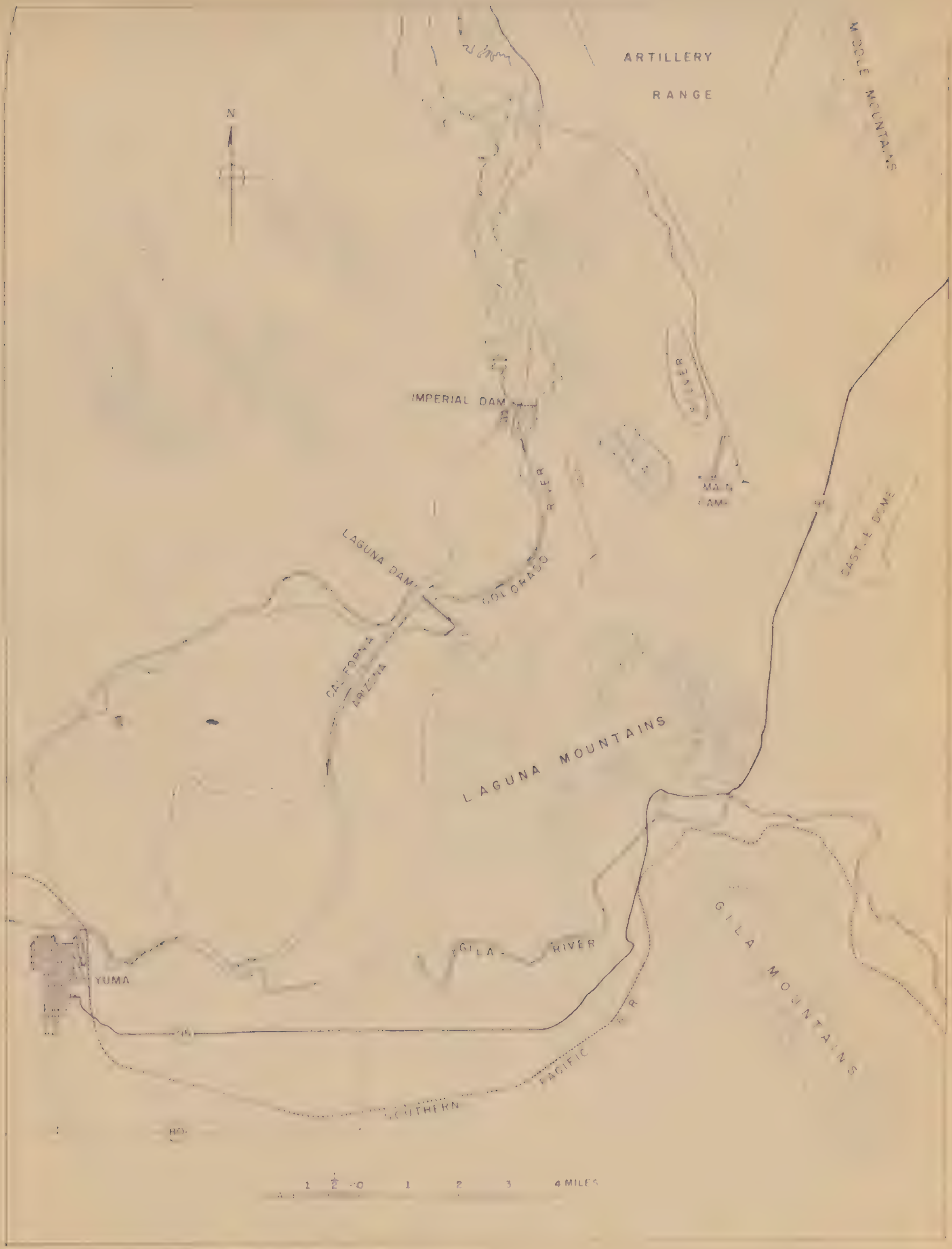

Figure 1
Yuma, Arizona and Vicinity.

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Figure 1
Task Force Furnace - Main Camp

Figure 3
Typical Tank Driving Terrain - Task Force Furnace

Figure 4
RL Truck with Evaporative Cooler

In the study of man in the desert, it is useful to summarize some of the environmental factors in terms of working and sleeping hours. The vehicles under test usually stayed in the motor park for servicing and repair until about 1000 hours. They were then driven to the test site, operated according to the test schedule, and returned to the base camp by 1630. Conditions typical of the working hours at the driving course or firing range are given in Table 1 at 1000, 1200, and 1500 hours. Lights went out at 2245 hours and 2300 was, therefore, taken as the start of the sleeping period; 0530, for reasons mentioned below, was assumed to be representative of the end of that time. Table 1 summarizes the dry bulb temperatures during working and sleeping hours.

The daily cycle of dry bulb temperature was marked by an average early morning minimum at 0517 hours (range 0230 to 0630 hours). Since breakfast was at 0600, the daily minimum and the end of the sleeping period fell at about the same time; therefore, 0530 was used in Table 1. The temperature rose quite rapidly at first but reached its maximum (or the first record of a continued, steady maximum) as early as 1300 or as late as 1630 hours, the average being 1442.

Since man in the desert depends for survival upon the cooling effect of the evaporation of water, it is of especial significance to consider the wet bulb temperatures. These are given in Table 1. The relative constancy of wet bulb readings compared to dry bulb is a corollary of the fact that the amount of water vapor in the air, i.e., the absolute humidity, is quite constant, although the relative humidity is highly variable. For that reason data on relative humidity are of little value and are not presented.

Air movement is essential for evaporative cooling to be effective. From Table 1 it may be seen that the breeze was never excessive during the stated periods and the average was twice as great during the day as at night. The data fail to indicate that the wind was frequently gusty. Small local whirlwinds, while spectacular and sometimes a nuisance around the base camp, were of no practical significance.

Rain was absent in this area. Showers threatened several times but only a few drops fell. Heavy rainfall occurred not many miles away on several occasions, and a completely rain-free July could not regularly be counted on in this region.

Solar radiation was measured with a General Electric radiation meter, type DW-60. The mid-day maximum was from 1.2 to 1.3 cal/cm^2/min, which agreed well with readings from an Eppley pyrheliometer set up by an observer from the Office of the Quartermaster General.

TABLE 1

AGF TASK FORCE FURNACE
Yuma, Arizona, July 8-30, 1947

A. Outdoor air temperatures - Shaded dry bulb.

DEGREES FAHRENHEIT

Date	Working Hours			Sleeping Hours	
July 1947	1000	1200	1500	2300*	0530
Highest	[illegible]	107	[illegible]	[illegible]	[illegible]
Lowest	[illegible]	[illegible]	101	[illegible]	71
Average	[illegible]	[illegible]	[illegible]	91.2	[illegible]

B. Outdoor air temperature - Shaded wet bulb

DEGREES FAHRENHEIT

Date	Working Hours			Sleeping Hours	
July 1947	1000	1200	1500	2300*	0530
Highest	75	76	76	74	73
Lowest	58	61	62	58	51
Average	67.9	69.1	70.0	65.8	62.5

C. Outdoor air movement

MILES PER HOUR

Date	Working Hours	Sleeping Hours
8-30 July	1000 to 1630	2300* to 0600
Highest	[illegible]	5.0
Lowest	4.1	1.1
Average	[illegible]	[illegible]

* On the preceding date.

SECTION II

ENVIRONMENTAL STRESSES ON TANK CREWS

I. METHODS AND PROCEDURE

To determine the effects of desert environment on personnel operating tanks the following measurements were routinely made:

1. Air temperature, dry bulb, with a mercury thermometer held in the vehicle or mounted in the sling psychrometer or portable motor driven psychrometer.

2. Temperature, wet bulb, with a mercury thermometer having the bulb covered with a clean wick kept wet with distilled water.

3. Surface temperatures of wall of vehicle, by mercury thermometers laid against the surface and held in place by a pad of cotton overlaid with adhesive tape.

4. Air movement by an "Alnor Velometer," which indicates in feet per minute the linear rate of air flow past its orifices.

5. Carbon monoxide was estimated with the Bureau of Standards rapid field indicator.

These data were recorded at frequent intervals in the observers' notebooks while the vehicles were standing or in motion on one of the driving courses.

The radiation meter was not sufficiently sensitive to measure radiation of heat from walls to occupants of tanks. It is certain, however, that the radiation level was far below that from sun, sky and desert outdoors, and the crew members were in a much more favorable position than the men outside. The dry bulb temperature is the best available measurement of heat input from the environment to the human body, which together with metabolic heat, must be dissipated by evaporative cooling.

These observations were made on Light Tank M-24, Medium Tank M-26, Armored Utility Vehicle M-44, Medium Tank M4A3E8 and the Canadian Snowmobile, Mark II.

II. RESULTS

A. Light Tank M-24

Inasmuch as this vehicle has been very thoroughly studied at Fort Knox (6), the observations at Furnace were limited to a few rides by Medical Department Field Research Laboratory observers without making detailed measurements of temperatures and ventilation. There appears to be no reason to expect impairment of crew efficiency under the prevailing desert conditions.

B. *Medium Tank M-26*

Medical Department Field Research Laboratory observers made several trips in this vehicle over Castle Dome course on different days. It was operated with hatches closed but a number of the smaller openings (e.g., machine gun ports) were not sealed and these contributed to the efficacy of the ventilation especially when the vehicle was in motion. When running, the tank had internal air temperatures only a few degrees above those outside and a sufficiently vigorous air movement to permit prompt evaporation of sweat. Only the driver, whose body heat load was augmented by exercise and whose sweat rate was therefore greater, arrived at the end of the 10-mile circuit with his clothing drenched with unevaporated sweat. When the vehicle was stationary and closed, there was little air movement, especially in the fighting compartment, and therefore furnished an environment of very poor evaporative cooling power for the crew. No carbon monoxide was found by the detection methods used.

Firing of the 90mm. gun of the M-26 tank was observed several times although the laboratory truck was not equipped to do complete gas analyses as has been done at Fort Knox (7, 8). Spot carbon monoxide analyses were done with the Bureau of Standards analyzer. Two rounds, fired within a minute in the M-26 with hatches closed, always resulted in an apparent carbon monoxide concentration of 0.1%. This is about one-half of the permissible concentration for 30-minute exposure, but it is greater than the permissible limit for prolonged breathing (7). If breathed for half an hour it would have produced marked, but probably not fatal, results. The other gases liberated into the turret were highly irritating and of sufficient concentration to cause the crew to open the hatches after each two rounds.

In the final test the hatches were closed, machine gun and other openings were sealed, and the blower operated at maximum capacity. Under these conditions no air movement was detected in the turret. Two rounds were then fired, the second shell casing being returned to the breech to keep it sealed. The turret air was sampled for carbon monoxide immediately and at 2, 4, 6, and 10 minutes after firing. Each sample showed an apparent carbon monoxide concentration exceeding the upper limit of the instrument, that is 0.1%, with only a slight indication that the concentration was being reduced by the action of the blower.

C. Armored Utility Vehicle M-44

This is a lightly armored infantry carrier mounted on an M-26 chassis. Places are provided for driver, assistant driver, commander and 21 passengers. During several runs made on different days over the Silver course, measurements were made of temperatures and air movement. The walls of the vehicle became very hot, exceeding 140°F, the upper limit of the thermometers. The air movement in the passenger compartment was very low and, with the hatches closed, the temperatures reached 120° dry bulb and 84° wet bulb.

Full Load Trial. Arrangements were made by the chief test officer for a detail of enlisted men to fill the passenger compartment, and the M-44 was run over the Castle Dome course with three MDFRL observers also riding. The vehicle left the motor park at 1337 hours, 25 July 1947 with a full complement of personnel and all hatches closed. One observer rode in the assistant driver's seat and two in the passenger compartment. The vehicle ran out to the Castle Dome course and around it in the counter-clockwise direction as far as the control point (approximately 12 miles), with hatches still closed but with short stops every 15 minutes to read the instruments. At the control point the men were permitted a 15-minute break to get out to stretch and drink. The run was then resumed completing the course and return to the motor park.

The measurements of dry bulb and wet bulb temperatures, air movement and temperature of the outer wall of the vehicle are given in Table 2. It should be noted that although the dry bulb temperature was fairly high (maximum 120°F.) and the air movement was very slight, there was still enough evaporative power to prevent accumulation of large amounts of unevaporated sweat and overheating of personnel. The still air temperature in the right passenger compartment was higher than the dry bulb temperature, probably because the thermometer was near the roof where convection and radiation would both tend to make it hotter.

D. Medium Tank M4A3E8

This vehicle was studied after an insulating cover over the transmission and final drive had been installed. Observers rode a circuit of the Castle Dome course on 30 July 1947. The data are included in Table 3. No carbon monoxide was found.

E. Canadian Snowmobile, Mark II

Observations were made in the Snowmobile on the Castle Dome Course by Medical Department Field Research Laboratory observers on 28 July 1947. Many measurements were made with dry and wet bulb thermometers, but the velometer was not used when running with the doors open because it would have been damaged by the dust, which was exceedingly heavy.

A summary of the observations is given in Table 4. The outdoor temperatures were never lower than 106°F. during the test, and when operating with hatch and doors closed the inside air temperature rapidly rose due to the heat from the roof and walls. The wet bulb temperature also rose on account of the water evaporated from the very actively sweating crew members. Within a very few minutes the situation became intolerable and the hatch had to be opened. With wet bulb temperatures of 96°F. or higher, there can be little evaporative cooling of the human body and its temperature will, therefore, rise. The rate of rise and the permissible time of exposure depend on the dry bulb temperature, radiation, and especially on the rate of heat production by the subject, none of which was known in this test. Operation with the roof hatch open brought the temperature down toward outdoor values and induced enough air movement to promote effective evaporation of sweat.

TABLE 2

ARMORED UTILITY VEHICLE M-44

FULL LOAD TRIAL

Time	Operation	Doors & Hatches	Blowers	Temperatures: Asst. Driver's Space, Dry Bulb	Asst. Driver's Space, Wet Bulb	Passenger Space, Right Side, Dry Bulb	Passenger Space, Right Side, Wet Bulb	Passenger Space, Left Side, Bulb	Passenger Space, Left Side, Wet Bulb	Outdoors, Dry Bulb	Outdoors, Wet Bulb
Hours				°F	°F	°F	°F	°F	°F	°F	°F
1337	Standing	Open	Off	-	-	106	80	110	[illegible]	105	76
1340	Running	Closed	On	110	82	-	-	113	[illegible]		
1355	"	"	"	112	82	109	82	115	81	105	76
1410	"	"	"	114	83	109	82	116	80		
1425	"	"	Off	111	80	109	85	120	83	106	77
1440	"	"	On	110	80	108	82	116	77		
1505	"	"	"	112	85	109	79	111	78	107	75
1520	15 Minute Rest Standing	Closed	Off	112	86	109	82	120	81	107	73
1535	Running	"	On	114	80	110	80	117	78		
1550	"	"	"	112	82	110	-	120	79	106	72
1605	Standing	Open	Off	-	-	111	-	118	77		

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TABLE 3

MEDIUM TANK M4A3E8

Time	Hatches	Operation	Asst. Driver's Area			TEMPERATURES					Air Movement in Turret
						Turret			Outdoors		
			Dry Bulb	Wet Bulb	Front Wall	Dry Bulb	Wet Bulb	Roof	Dry Bulb	Wet Bulb	
Hours			°F	°F	°F	°F	°F	°F	°F	°F	Ft/Min.
[illegible]	Open	Standing	116	82	123	109	73	126	106	71	0
1335	Closed	"	119	85	123	113	78	126			50
1350	"	Running	118	84	125	112	75	126			50 - 100
1405	Open	"	114	81	123	113	75	126	108	71	50
1420	"	"	116	79	123	110	77	126			70
1435	"	"	115	77	124	114	75	126	107	71	80 - 100
1445	"	"	114	76	124	112	75	126			80 - 100

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TABLE 4

CANADIAN SNOWMOBILE

Time	Operation	Roof Hatch	Doors	Psychrometer		Thermometers in Crew Space		Air Movement	Outdoor Temperatures*	
				Dry Bulb	Wet Bulb	Front	Rear		Dry Bulb	Wet Bulb
Hours				°F	°F	°F	°F	Ft/Min.	°F	°F
1325	Standing	Closed	Closed	110	84	113	109	0	108	73
1340	Running	"	"	125	96	125	110	0		
1355	"	Open	"	117	84	117	114	50 - 100		
1405	"	Closed	"	123	97	123	120	0	106	73
1415	"	Open	"	119	87	119	113	50 - 100		
1430	Standing	"	Open	118	80	118	113	-	107	73
1445	Running	"	"	118	80	118	114	-		
1457	"	"	"	119	83	118	113	-	108	73
1515	"	"	"	115	79	119	113	-	108	73
1522	"	"	"	115	84	115	111	-		

* At Base Camp

III. CONCLUSIONS

None of the vehicles tested, with the exception of the Snowmobile, subjected their riders to conditions of temperature, humidity, and air movement which produced markedly deleterious effects. It is undoubtedly true that men working under the conditions described above are not as efficient as they would be in a temperate climate. However, the absence of heat prostrations can be taken as evidence that a fair margin of safety was present, for even the more susceptible among the personnel were able to carry out their normal duties. Only one subject (in the M-4A) showed signs of near collapse.

The Snowmobile, as could be predicted, will require drastic changes in its ventilating system if it is to be used in the desert.

PHYSIOLOGICAL OBSERVATIONS

I. INTRODUCTION

The desert, unlike the humid jungle, places a solution at hand to the problem of how man can exist in high ambient temperatures and in the presence of a considerable flow of radiant heat from the environment to the body. The solution lies in the principle of evaporative cooling. The human body uses that principle very effectively but in so doing is compelled to maintain internal water and salt balances with considerable accuracy in the face of rapid rates of turnover of both water and salt. Life in the desert, therefore, hinges largely upon the ability of the organism to obtain, absorb, and excrete appropriate quantities of water and to maintain its salt balance within tolerable limits.

Water was always available at Furnace and each group going to a range of driving course carried ample supplies, usually in thermally insulated containers. Each man's thirst, or appetite for water, was therefore the controlling factor over his fluid intake. His rate of sweating was controlled by internal bodily factors as influenced by his environment and activity. The kidneys would excrete any excess of water over and above the minimum necessary for the excretion of non-volatile wastes in as concentrated a form as the renal mechanism could produce. The production of dilute urine would be a sign that one's fluid intake exceeded the essential minimum.

II. PROCEDURE

For practical purposes, specific gravity measurements were used as an index of urine concentration. Osmotic concentration calculated from freezing point depression might be preferred, but the apparatus for making freezing point determinations was broken in shipment. Specific gravities were determined by the falling drop method.

III. RESULTS AND CONCLUSIONS

A. Observations on Tank Crewmen

Urine collections were made on two days from tank crewmen selected only on the basis that the duration of the urine formation period was known. The data on rate of urine production and specific gravity are given in Table 5. The rate of urine formation was low, but not as low as that found in severe dehydration. The specific gravity was but a little less than the maximum to be expected from a group of such subjects. It is concluded therefore, that these men were barely keeping themselves properly hydrated in response to their normal thirst.

TABLE 5

URINE FLOW AND CONCENTRATION - TANK CREWMEN

Date July 1947	Subject	Time of Voiding Hour	Duration of Period Minutes	Urine Flow ml/min	Urine Specific Gravity
15	1	1500	300	0.52	1.0226
	2	"	250	.53	1.0263
	3	"	250	.62	1.0229
	4	"	375	.52	1.0306
	5	"	390	.48	1.0307
	6	"	420	.42	1.0302
27	7	1520	530	.43	1.0319
	8	"	320	.31	1.0331
	9	"	300	.42	1.0306
Averages			358	0.48	1.0288

B. Observations on Technical Observers

In order to obtain an approximate description of the water balance of persons exposed to the prevailing conditions at Furnace, each member of the Medical Department Field Research Laboratory detachment undertook to estimate and record all water drunk, the water content of food eaten, and the volume of all urine produced for a period of several days. The data are summarized in Table 6. The average fluid intake, 7239 ml., was of course augmented by a small amount of water produced by metabolic processes which could not be estimated with enough accuracy to be included. The average specific gravity of the urine of each individual varied from 1.0221 to 1.03A1, the average of all subjects being 1.0298. In general, each subject maintained a uniformly high specific gravity, there being only 3 samples as dilute as 1.020 among 65 specimens examined.

The data on chloride excretion show that all subjects except No. 4 were ingesting enough salt, either with their food or by means of salt tablets added to the drinking water, to provide the quantity lost in the sweat and an excess excreted by the kidney. Subject No. 4, whose urine was almost chloride free and who therefore may have had a chloride deficiency, had been nearly prostrated while riding the M-44 on Silver Course. At that time the temperatures in the vehicle were 120°F. dry bulb, and 94°F. wet bulb and, with the hatches closed, the air movement was very low. No other members of the crew, however, were adversely affected, and it is possible that subject No. 4 was more than ordinarily heat sensitive due to a salt deficiency.

On the days following those on which the data of Table 6 were collected, and while measurements of fluid intake and urinary output were

TABLE 6

WATER BALANCE STUDIES
(24 hour periods)

Date July 1947	Subject	Weight	Fluid Intake	Urine		Urine Output ÷ Fluid Intake	Urinary NaCl
				Output	Average Flow		
Day	No.	Pounds	ml	ml	ml/min	%	grams
8	1*	175	8215	821	0.57	9.9	11.3
9			8340	884	0.61	10.6	6.8
15	1**	175	7150	649	0.45	9.0	6.1
16			7445	734	0.51	9.8	5.4
15	2	131	8300	750	0.50	9.0	4.4
16			4120	650	0.45	15.7	6.0
15	3	165	8390	1230	0.86	14.6	13.1
16			5720	1330	0.89	23.3	14.8
15	4	200	8565	1011	0.63	11.8	0.3
16			6655	665	0.50	9.9	0.2
15	5	135	6470	550	0.37	8.5	7.4
16			4950	590	0.41	11.9	6.1
15	6	220	9340	870	0.59	9.3	10.3
16			7780	840	0.59	10.8	11.1
AVERAGES			7239	826	0.57	11.4	

* 5 grams of NaCl daily in addition to the usual salt content of the diet.

** No extra NaCl

being continued, tests were made on three subjects to determine if they were dehydrated, although they always could drink as much as they wished. The tests consisted in noting the effects on urine flow and specific gravity, and upon chloride excretion of the subcutaneous injection of 0.3 pressor units of pitressin. This dose will cause a practically complete inhibition of water diuresis in man, and will cause him to produce urine of nearly maximum concentration. If the subjects were dehydrated, they could be expected to be secreting antidiuretic hormone from the neurohypophysis at a rate sufficient to show the maximal effect on the water reabsorbing mechanism of the renal tubules. The data are shown in Table 7.

Pitressin contains a substance which has the same renal effects as the naturally secreted post-pituitary antidiuretic hormone. The observed average rise of 52% in the urine flow is contrary to that expected from the primary effect of pitressin, but it can be explained by reference to the secondary effect of the drug, viz., the promotion of chloride excretion. It will be noted that the excretion of NaCl (calculated from chloride analyses) rose to almost the same extent (57%), and the insignificant changes in urinary chloride concentration and specific gravity suggest that in these subjects there was already present enough circulating antidiuretic hormone to stimulate water reabsorption by the renal tubules to the limit of their capacity. However, the addition of a further amount of the hormone could and did reduce the tubular reabsorption of chloride with the resultant increase in chloride excretion. Since the tubules could not produce a more concentrated urine, the extra chloride required an increased bulk of urine.

It is concluded that these subjects, while showing no objective signs of dehydration, were in such a state of water balance that a reduction of water intake or an increase in sweating might have soon shown obvious effects. During their waking hours, they took in fluid at an average rate of about 7 ml. a minute or 420 ml. an hour. A few attempts were made to produce a water diuresis, but great difficulty was encountered in getting subjects to drink an extra liter of water. It appears that the ability of the organism to accept, retain, and absorb water may be a limiting factor in any environment where maximal sweating is induced. If this is the case, the likelihood of severe dehydration, even with ample drinking water freely available, becomes an important factor of survival.

TABLE 7

DESERT - EFFECTS OF PITRESSIN

Urine periods before (B) and after (A) 0.3 Unit of Pitressin

Subject	Urine Flow B	Urine Flow A	[Cl] B	[Cl] A	NaCl B	NaCl A	Specific Gravity B	Specific Gravity A	Changes: A/B Volume	Changes: A/B [Cl]	Changes: A/B NaCl	Changes: A/B Sp.gr.
No.	ml/min		mEq/L		mg/min							
5	.76	.83	186	177	.83	.86	1.0259	1.0328	1.09	.96	1.04	1.0067
3	.71	1.59	163	174	.68	1.61	1.0251	1.0279	2.24	1.07	2.37	1.0027
1*	.26	.40	164	174	.25	.41	1.0285	1.0252	1.54	1.06	1.64	.9967
1**	.38	.46	136	137	.30	.37	1.0239	1.0239	1.20	1.01	1.23	1.0000
Average									1.52	1.03	1.57	.9995

* 5 grams of NaCl daily in addition to the usual salt content of the diet.

** No extra NaCl.

SECTION IV

MISCELLANEOUS OBSERVATIONS

I. TESTS OF PROTECTIVE CLOTHING

Medical Department Field Research Laboratory personnel participated in the physiological aspects of the tests of three varieties of gas protective clothing, one type of impermeable suit, and two varieties of permeable garments.

The impermeable suit is worn with a gas mask installed in an impermeable hood. The subject's exhaled air enters the hood and reaches the outside through the neck closure, thus improving the effectiveness of the hood-jacket seal against the ingress of gas. Evaporation of sweat is completely prevented by the suit and the cooling effect of that process is therefore lost. The test was designed to study the effects of evaporative cooling from wet cotton outer garments, worn over the suit, on the comfort and presumptive working capacity of the wearer.

Two different types of permeable protective suits were used, each consisting of shorts, socks and herringbone twill jacket and trousers. The first, or "carbon" type, was impregnated with activated carbon, layered on the inside of the outer garments and incorporated in nylon threads in the socks and shorts. The second type, designated "CC2" had a highly chlorinated compound incorporated as a foam in the fabric. The purpose of the test was to obtain garments which had been worn for various lengths of time under field conditions in order to estimate the permanency of the chemical protection.

During the tests of the impermeable suits, temperatures taken under a pyramidal tent with the sides up were: at 1350, 110°F. dry bulb, 67°F. wet bulb; at 1454, 113°F. dry bulb, 67°F. wet bulb. Air movement at the test site was measured with the Velometer at values from 700 to 1700 feet a minute, or about 15 miles an hour, which was also the value given by the integrating anemometer at the weather station 100 yards away. Water was supplied from a tank truck by hose or shower spray delivery at 96°F. The subjects were always exposed to the sun.

The permeable suits were tested on a detail of 20 men who wore the suits daily from 1 to 6 days during their routine duties and while making a 4-mile road march. An observer from this laboratory accompanied them on one of the marches to note the effects on the men. The march was from 0830 to 1030 hours and proceeded from the camp area to State Highway 95 and return. The temperature was 94°F., humidity 36%, and wind velocity 7 mph. The men sweated profusely but the conditions were not especially severe and there were no adverse reactions. No difference between the two suits was noted. The men were examined daily at 1600 hours by the Task Force Surgeon, and some irritation was found,

especially around the waist, in some of the men wearing the CC2 suits. Much carbon was deposited on the skin from the carbon clothing and was said to have a possible abrasive effect not noted by our observers.

The first impermeable suit to be tested included rubber boots and hooded gas mask. Over these, the subject wore cotton pants, jacket and hood cover. He was wet down once with the hose while two of the observers assisted him in working the water into the cotton fabric by hand. A mercury thermometer, when placed against the rubber under the wet cloth, indicated temperatures varying from 75 to 80°F. The subject reported that he was comfortably cool, but except for a small amount of walking, he engaged in very little activity.

Two other men wore similar suits from 1440 to 1543 hours. Two different weights of cotton pants and jacket were worn but no difference in effect was noted. Each was re-wet twice during this exposure. One of the wettings was done to one subject by the other, using one canteen (975 ml.) of water. That amount of water gave a fairly complete wetting of the suit but it required six minutes to do it. As the coverings dried the men reported that their faces became hot first. Copious sweating of the face was seen. The feet of all subjects became very hot from the radiant heat absorbed by the black rubber boots. The subjects engaged in short periods of marching and found the evaporative cooling to be sufficient to dissipate the increased metabolic heat output.

The permeable suits appeared to raise no physiological problems related to their gas absorbing properties. The matter of skin irritation requires further study.

It is concluded that evaporative cooling of a man enclosed in completely impermeable garments is highly effective under the conditions of these tests, viz., air temperature as high as 113°F., wet bulb 67°F., 15 mph, wind velocity and full solar radiation. It is absolutely essential that the outer garments be kept wet, otherwise, intolerably high temperatures will result in a very short time. To this end it is suggested that the cotton garments be wet before being put on, and that the insertion of some spongy material at the top of the hood, over the shoulders and around the thighs be tried in an effort to lengthen the re-wetting intervals.

II. HYGIENIC OBSERVATIONS

A. Water and Salt Supply

There was plenty of water at Task Force Furnace and no studies were made of the effects of water restriction. As has been discussed above the men's thirst was sufficient to cause them to drink about 2 gallons (average 7.24 liters = 1.93 gal.) of water daily. That amount was recommended as the minimum daily ration for mild desert conditions in an earlier report from this laboratory(9). Most men found that the use of salt tablets was not necessary, and a few who took them reported gastric distress. The latter was always related to swallowing the

tablets (0.5 gram) whole, which has been reported (9) to be the source of gastric irritation.

The water delivered at the pipe-line faucets became very hot so that it was usually unpalatable, but evaporative Lister bags furnished a cooler source. Ice water was available but is not desirable when large quantities have to be drunk.

On some afternoons the piped water was above 130°F., too hot for a direct shower bath. This was remedied by a change in the pumping schedule, the camp reservoirs being filled at night.

B. Evaporative Coolers

The principle of evaporative cooling has been applied to military vehicles, e.g., the army ambulance. Studies on this vehicle at this laboratory (10) showed that the cooler was an efficient and useful aid in regions of low humidity.

A cooler was constructed at Fort Knox and was installed at Furnace at one of the windows of the laboratory truck (Fig. 4). A circulating pump served to keep a loose pad of excelsior thoroughly wet, and a 16-inch desk fan forced outdoor air through the evaporator. This device reduced the temperature in the truck by about 10°F. without increasing the humidity enough to interfere with human comfort. Several other installations at Furnace, and a large number in Yuma, were in continuous and successful use.

III. DESERT ANIMALS

A great deal of useful information has been gained by the study of animals which, by custom or necessity, are exposed to arid desert climate. It was planned to observe the desert animals whenever an opportunity presented itself and, if possible, to catch and study them. The kangaroo rat, *Dipodomys spectabilis*, was known to inhabit the region, and a few specimens were trapped. It was impossible to keep them alive in captivity for more than a day or two, probably because they could not retreat to the shelter of a deep burrow during the heat of the day. No data were obtained on their water intake and output or means of heat regulation.

The other animals seen or reported in the vicinity, viz., jack rabbits, deer, wild burros and wild horses, all had free access to water at the Colorado River a few miles away and in that way could avoid the most serious desert risk, dehydration .

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LABORATORY PHOTOPLANATOR

by

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1 April 1948

*Sub-project under Studies of Body Measurement as They Affect Physiological Efficiency. Approved 11 May 1946. MDFRL Project No. 6-64-12-05-(1).

No, 3

Project No. 6-64-12-05
Sub-project MDFRL 05-1
MEDEA

1 April 1948

ABSTRACT

LABORATORY PHOTOPLANATOR

OBJECT

Studies of body measurement as they affect physiological efficiency often require facilities for the comparative measurement of soft or easily deformable structures and also for the diametral measurement of very irregular shapes. In the case of structures of transient shape it is very desirable to have at hand a convenient means for obtaining a plurality of significant dimensions simultaneously.

RESULTS

A simple photoplanator based on the recently introduced "Enclosed-Zirconium-Arc" has been developed for laboratory and shop use. It has been used for the making and recording of quantity comparative measurements for dimensional range limit researches and also for the statistical recording of heterogeneous granular mixtures and fragmented samples.

CONCLUSIONS

For the making and recording of comparative measurements within its range of applicability photoplanation is often the easiest and most expeditious technique. The photoplanator offers many advantages in the dimensional recording of such diverse objects as meshes, air bubbles or oil droplets suspended in fluid media, egg yolks suspended in their whites, foams, and many other intangible or evanescent specimens.

RECOMMENDATIONS

None.

Submitted by:
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Approved: ________________
RAY G. DAGGS
Director of Research

Approved: ________________
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Lt. Col., M.C.
Commanding

I. INTRODUCTION

Photoplanation is not an entirely new research technique. Under various names it has been known for a long time as a versatile method of mensuration which lends itself particularly well to the measurement of easily deformable objects, to objects of very irregular shape, or to specimens exhibiting transient or variable forms. Recent developments in laboratory light sources have revived the technique and endowed it with greater precision and versatility than heretofore.

Essentially the technique of photoplanation consists in the employment of a beam of pure parallel light, substantially devoid of crossfire or abaxial rays, to cast a shadow of the object to be measured in such a fashion that the shadow will bear a dimensional relation of one-to-one to a plane projection of the object.

Such a shadow may be caused to fall on any suitable scale, grid or rule placed normal to the light beam and the shadow, of course, undergoes no change of dimension due to the act of measuring it. Usually the shadow of the object and the simultaneous shadow of a suitable transparent scale are caused to fall on a sheet of photographic paper or other photosensitive surface to obtain, by ordinary development and fixation processes, a permanent record which is suitable alike for observation, illustration, subsequent reference, or statistical compilation.

The reason that the technique has not been employed more widely heretofore has been the lack of a suitable simple light source. Outside of starlight, which is not sufficiently brilliant and is only occasionally available, the optical world has not had any convenient light source that has been substantially devoid of abaxial rays. In consequence, any apparatus for photoplanation has been very complicated optically and much too expensive for general use.

During the recent years of the war, research workers at the Western Union Company's Research Laboratories at Waterville, Long Island, New York, developed a new light source which is so small mechanically and so brilliant optically that it forms a useful source of substantially pure radial illumination and thereby lends itself to simple and comparatively inexpensive photoplanation.

This report concerns itself with the development of a laboratory photoplanator making use of the improvements in light source embodied in the Western Union Company's new arc light.

II. APPARATUS AND METHODS

A. The Zirconium Arc

This unusual light source is known as an "Enclosed Arc" or as a "Zirconium Arc", and it is commercially available in several standardized forms and sizes. It ordinarily consists of a very tiny tubular metal

electrode, only a few thousandths of an inch in diameter, filled with zirconium oxide and faced by an annular metal electrode, the two electrodes being sealed into a glass envelope or bulb of more or less conventional vacuum tube form. When an electric arc is struck between the two electrodes the energy of the arc heats the zirconium oxide first to fusion and then to vaporization, whereupon, a microscopic hemisphere of zirconium vapor, in a state of extreme molecular agitation, forms about the end of the tubular electrode and emits a white light of intense brilliance and substantially pure radial radiation.

A radial light source of this sort exhibits surprising properties not commonly conceived of in respect to a simple light source. For example, without accessory optical equipment such a lamp will serve as a contour projector or profile enlarger for the examination of machine tool forms and mechanical parts. Often the availability of an enclosed arc makes possible the inspection, by projection enlargement, of machined contours while the part is still in the forming machine. Or again, the lack of crossfire or abaxial radiation from these zirconium arcs makes it possible to project enlarged images of lantern slides or transparencies onto a projection screen without any associated optics.

Because of the clean radial characteristics of these zirconium arcs due to their essentially point-source dimensions, simple optical lenses function almost as well with them as highly corrected compound lenses and, hence, it requires only elementary equipment to convert their radial illumination into clean parallel beams eminently suitable for any type of photoplanation.

B. Initial Model Photoplanator

The need at this laboratory for a convenient and rapid means of measuring and comparing a large number of plastic molds of the external auditory canals of diverse human ears initiated the improvisation of a simple photoplanator consisting of a zirconium arc, a hand magnifying glass, a mount for the ear molds, and a transparent scale associated with a holder for sheets of photographic paper, all mounted on an ordinary laboratory ring stand.

This elementary photoplanator has been briefly described previously* but is here shown again in Figure 1. At the top of the ring stand is the zirconium arc, a ten-watt lamp having a source diameter of about .005 inch. This lamp is started and maintained by an electrical ballast and striking equipment shown in the case beside the ring stand. To start the arc it is only necessary to turn on the power switch and after a short interval press the temporary contact button until the arc strikes.

* J. H. St. John, Capt., M.C. Plastic Ear Mold for Communications Equipment. MDFRL Project No. 57-5, 30 September 1947

Just below the arc is a photographic shutter to interrupt the light beam and to measure off exposure periods proportioned to whatever photographic paper or other photosensitive material is being used. For most purposes an extreme contrast glossy paper is the best. Below the shutter a black paper tube prevents illumination from falling outside the magnifying lens which may be seen clamped enough lower than the arc so that the latter is at the principal focus of the lens.

Fastened to the base of the ring stand is a hinged paper holder having a circular opening cut in its hinged upper cover, and across the front of this opening there is cemented a transparent centimeter scale. Across the hinge side of the opening a slide is arranged for the insertion of transparent strips bearing numbers with which to identify successive records.

Figure 2 shows two photoplanograms of ear molds recorded on this apparatus, and Figure 3 shows a compilation of typical forms from many such photoplanator records.

Rat kidneys and other deformable objects were accurately measured and compared by this method. The facility of its use led to the construction of a more substantial but similar photoplanator as a permanent piece of laboratory apparatus.

C. New Laboratory Photoplanator

This new laboratory photoplanator is shown in Figure 4. It comprises the same elements as the preceding ring stand model with the addition of a transparent table on which to lay various objects when the instrument is in the vertical position. However, in this model the various parts are rigidly fastened together so that the instrument as a whole may be carried about from place to place without being thrown out of adjustment, and also so that it may be used in either a vertical or a horizontal position. Figure 5 shows the instrument as used horizontally to record heel profiles.

The optical system in this instrument remains as elementary as in the ring stand model. Indeed, the zirconium arc is the same arc but the field lens is larger in diameter, yielding a wider paralled beam and permitting the shadowcasting of larger objects. This optical system is shown diagrammatically in Figure 6.

In this new model there is a more convenient and critical adjustment of the position of the arc so as to obtain strictly parallel rays in the beam. This is easily effected manually by first setting an approximate position of the arc by the rod clamp shown at (a) in Figure 4 and then using the draw tube and the set screw shown at (b) for finer setting.

This final setting is facilitated by a very simple check in the following manner. A piece of black paper is folded in the middle and notched across the fold, as shown in Figure 7. The paper is then cut apart along the fold and one part, which we may call the "object half",

is laid on the object table. The other piece, which we will call the "reference half", is laid on the shadow plane facing the shadow of the object half, as shown in Figure 8. The exact matching of the reference half with the shadow half depends upon the precise parallelism of the light beam and is both easy to observe and very critical. With this procedure the photoplanator may be checked accurately or precisely reset in less than a minute.

It should be noted that once the halves are exactly matched for length for any one position of the object half, the match will remain perfect for all positions of the object half between the condenser lens and the shadow plane. Using vernier scales the match may be achieved to any reasonable desired degree of accuracy. When the matched adjustment is once set the true size ratio holds between the shadows of all objects introduced into the beam at any transverse position. Thus, objects may be compared with each other conveniently or, as in the case of the ear molds, with any convenient transparent scales or grids.

It is a simple matter to record the shadows of the objects and comparison scales on a sheet of photographic paper placed in the paper holder at the shadow plane and exposed by means of the shutter. Since the object shadow and the scale image are both subject to the same stretching or shrinking during the development and drying of the paper they preserve a sufficiently accurate relation to each other so that results may be accumulated during work and analyzed at any convenient time subsequently.

III. CONCLUSIONS

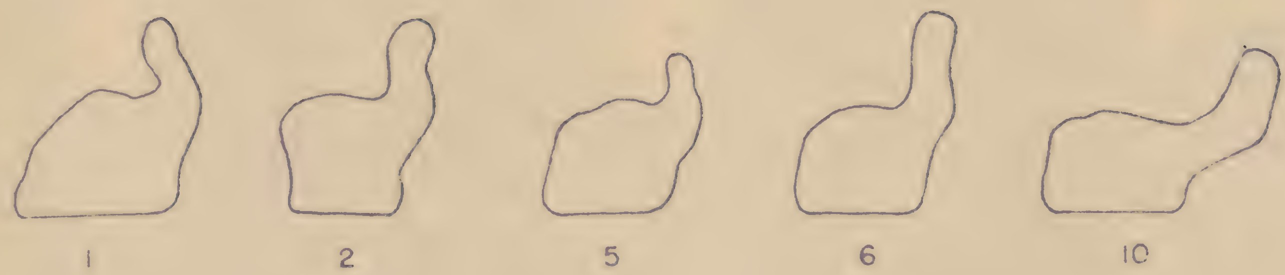
Several examples of photoplanation (Figures 9 thru 14) done on this new laboratory photoplanator are appended, including an example of template cutting for which the device is unexcelled.

It is felt that the simplicity and versatility of photoplanation with the zirconium arc is such that the general technique of photoplanation will presumably have an extended revival in research and industrial fields.

It is hoped that this brief exposition of the device may be sufficient to guide the reader toward those applications that may be of service in his sphere of endeavor.

FIG. 1 INITIAL MODEL PLANATOR

FIG 2. EAR MOLDS



PHOTOPLANOGRAPH TRACINGS OF REPRESENTATIVE PLASTIC EAR MOLDS

FIG. 3

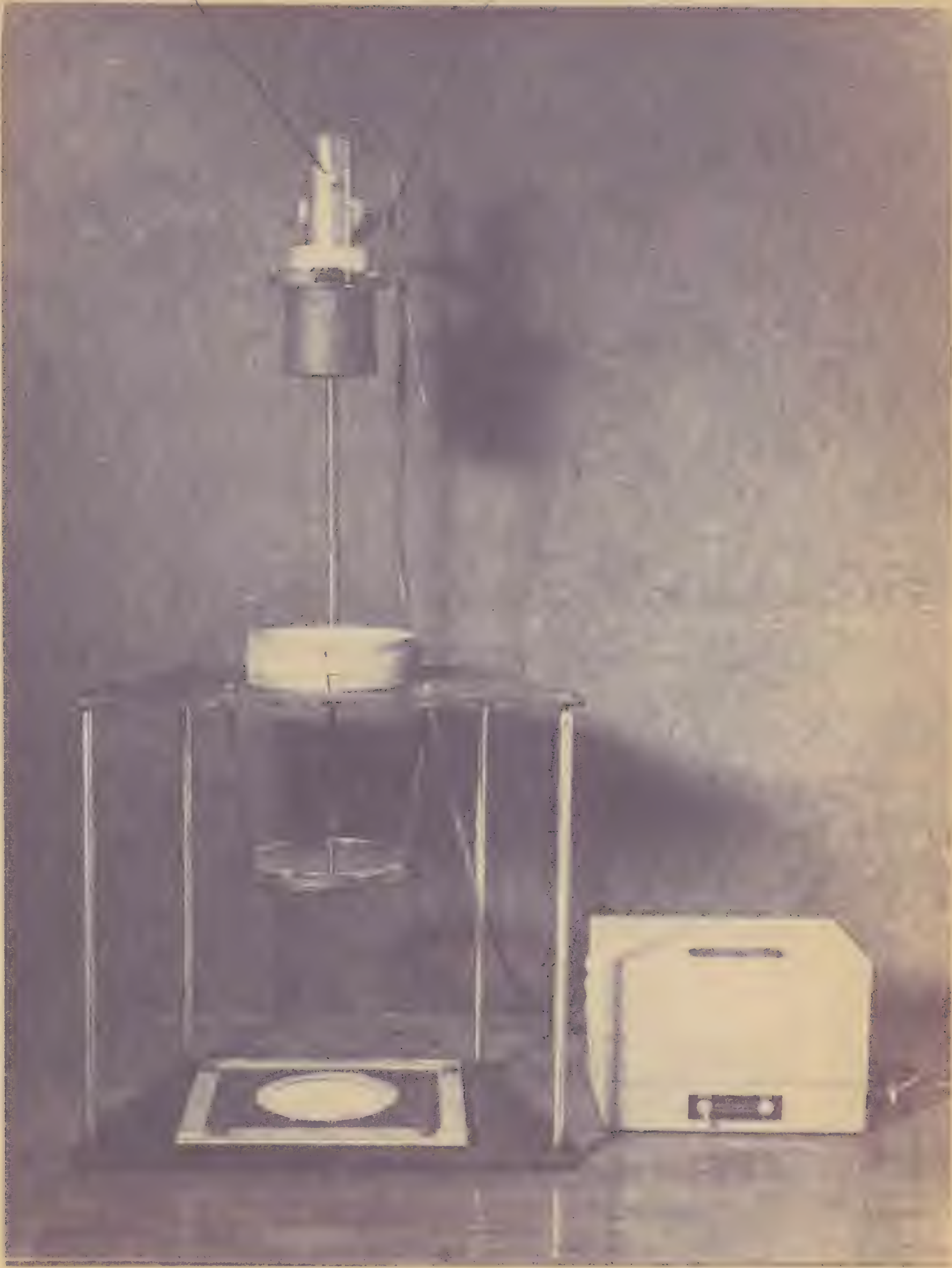


FIG 4 NEW LABORATORY PHOTOPLANATOR

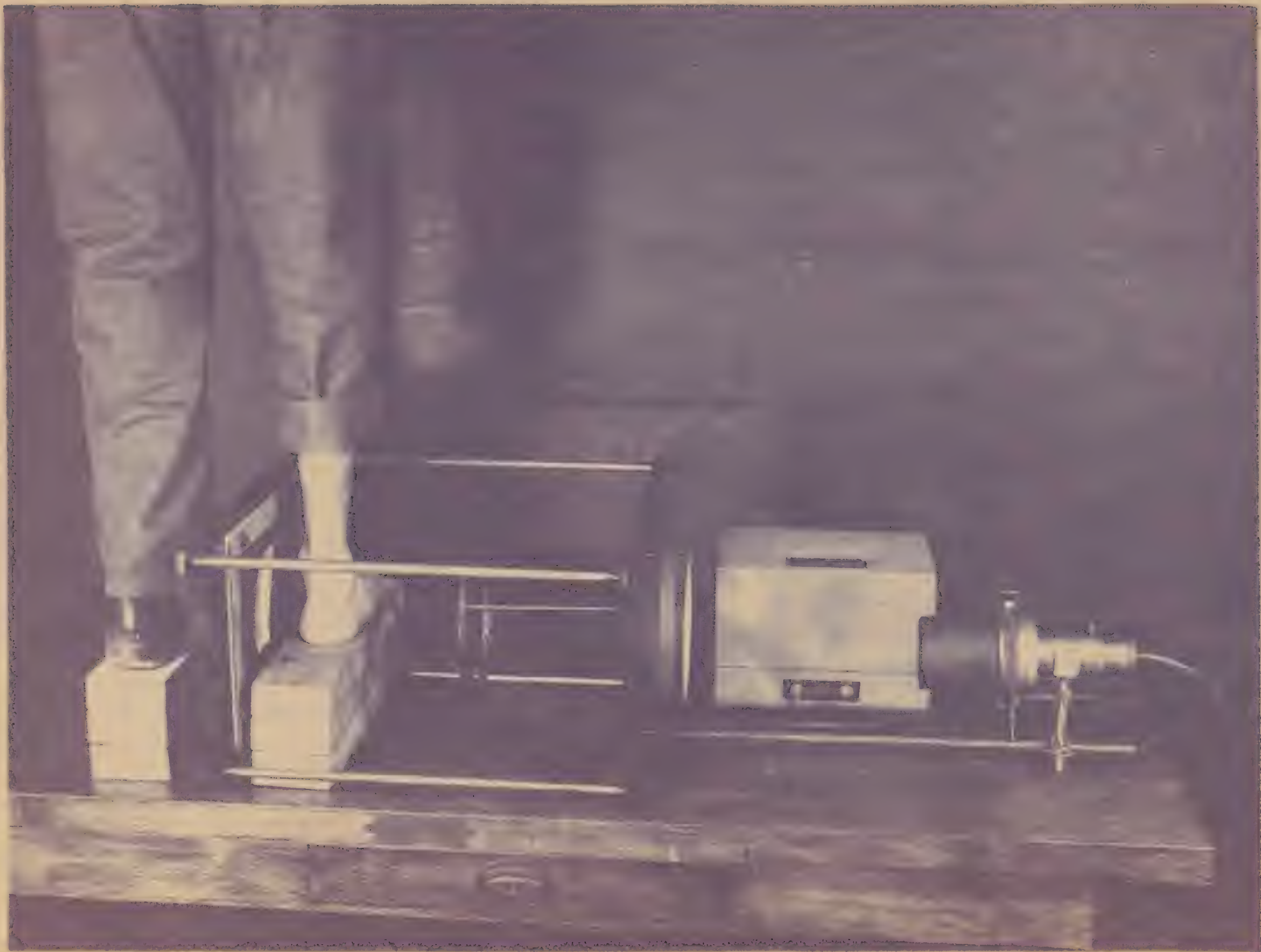
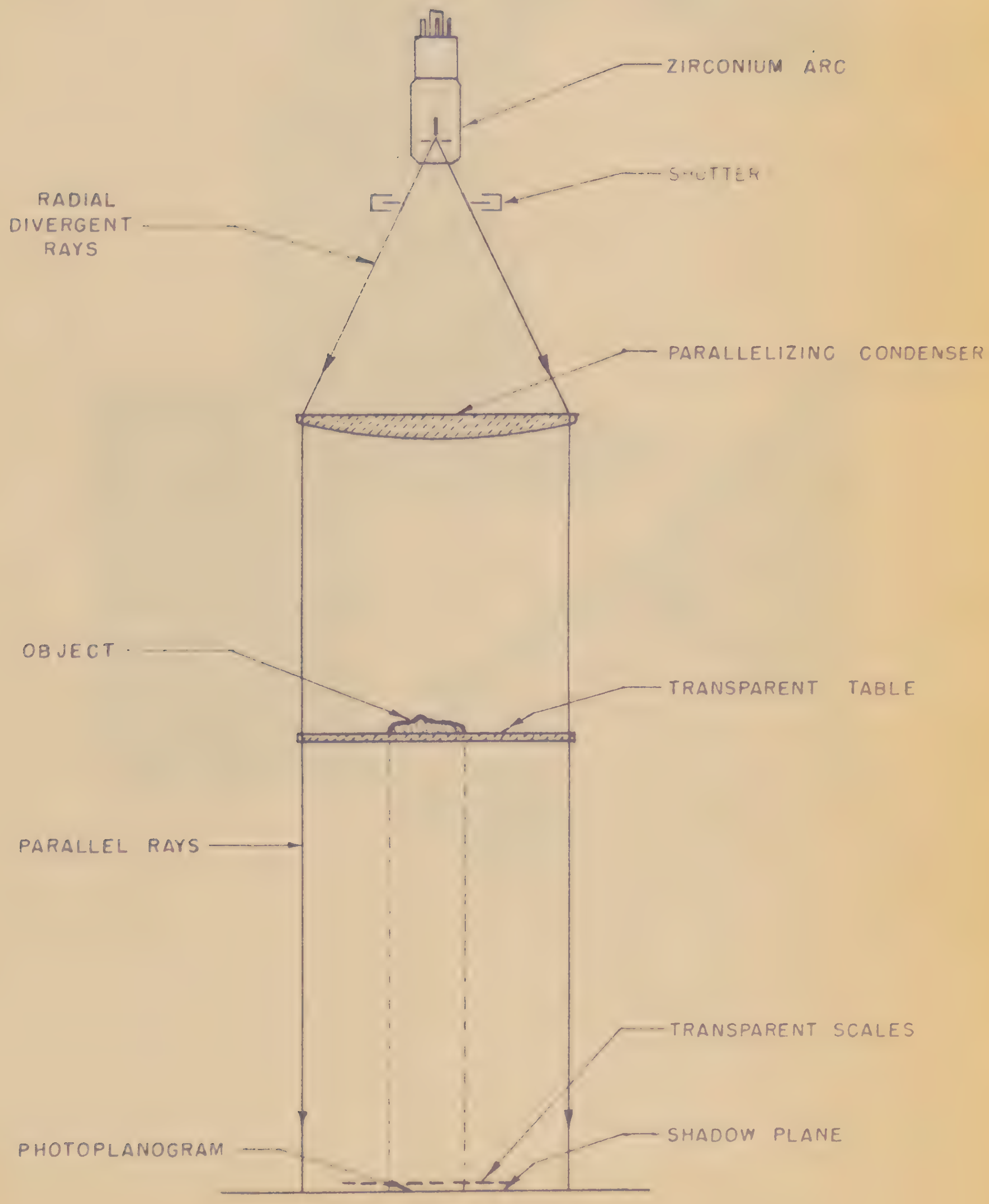


FIG. 5 LABORATORY PHOTOPLANATOR USED HORIZONTALY



PHOTOPLANATOR OPTICAL SYSTEM

FIG. 6

FIG. 7. NOTCHING FOLDED PAPER

FIG. 8. ARRANGEMENT FOR CHECKING PARALLELISM OF THE LIGHT BEAM.

FIG. 9 PROFILE OF HUMAN HEEL

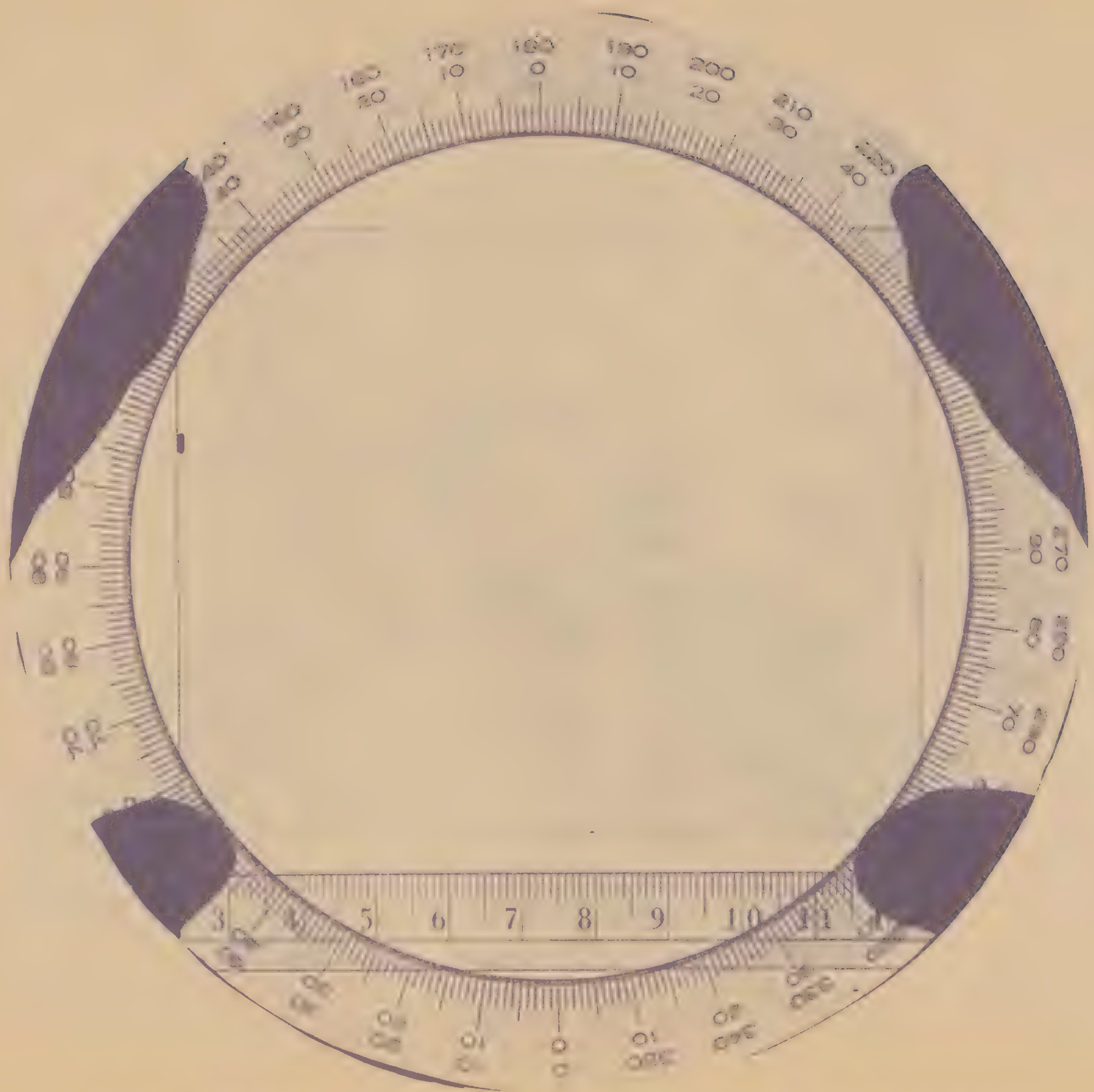


FIG. 10 TRANSPARENT FINGERPRINTS ON GLASS

FIG. 11 PHOTOPLANOGRAM FOR TEMPLATE

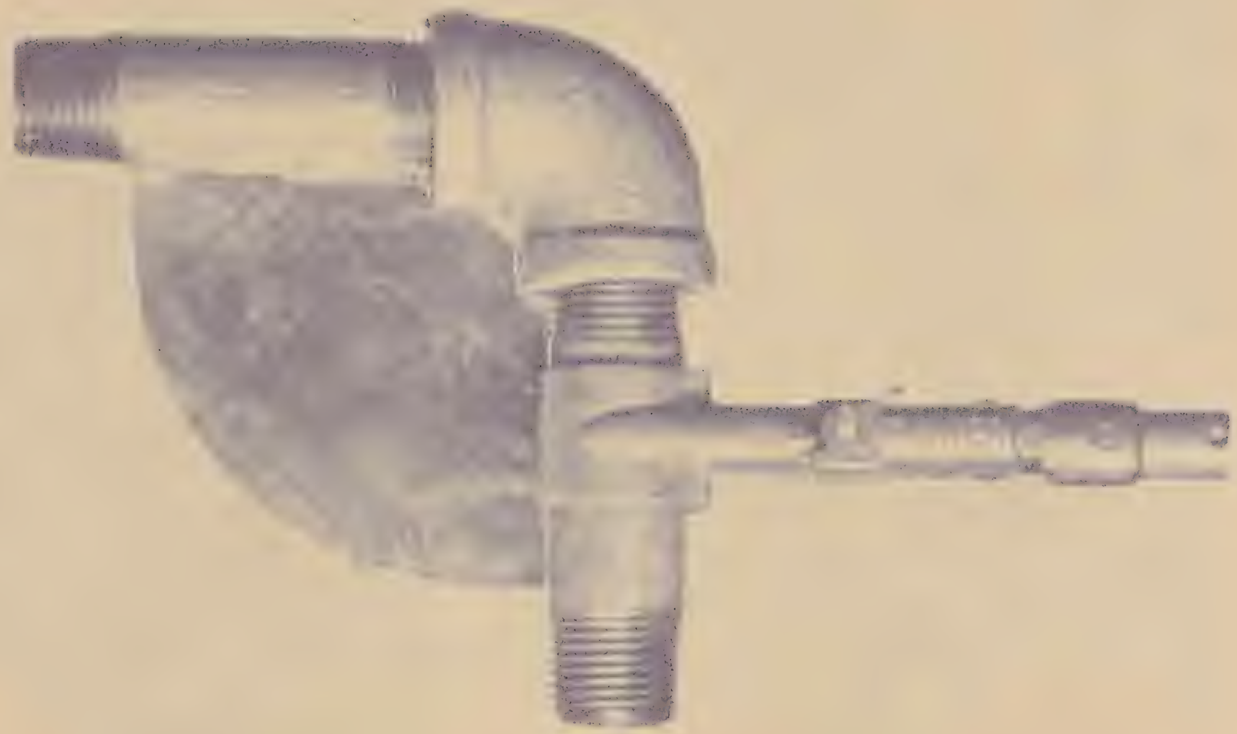


FIG. 12 TEMPLATE

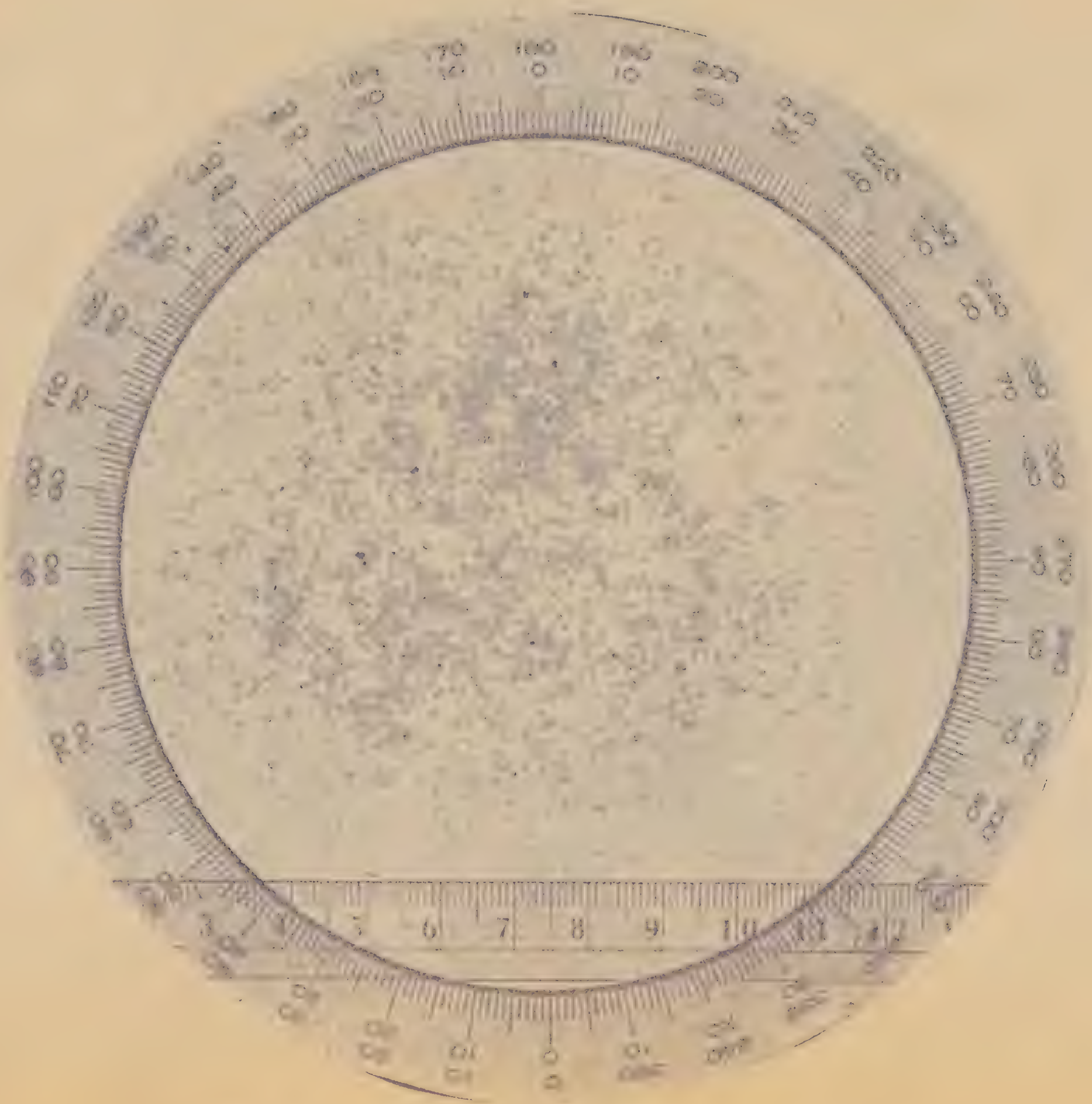


FIG. 13 SPHERICAL QUARTS GRAINS

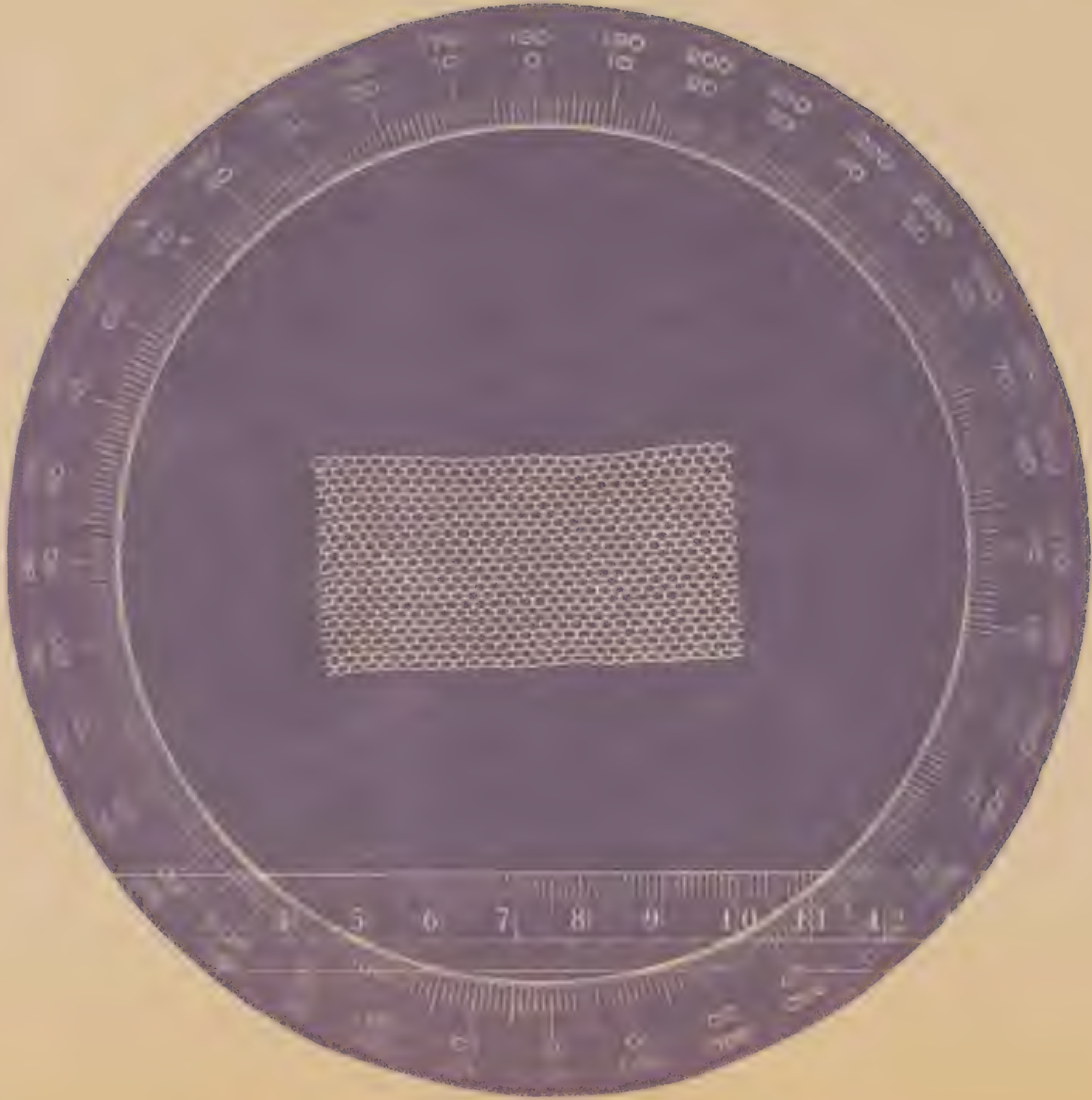


FIG. 14 TEXTILE NET

EFFECTS OF ATROPINE AND PILOCARPINE

ON HUMAN THERMOREGULATION*

by

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14 April 1948

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No. 4

Project No. 6-64-12-06
Sub-project MDFRL 06-8
MEDEA

14 April 1948

ABSTRACT

EFFECTS OF ATROPINE AND PILOCARPINE ON HUMAN THERMOREGULATION

OBJECT

To determine the manner and extent of compensation to the thermal stresses imposed by the injection of atropine and pilocarpine.

RESULTS

Complete thermal balance studies were made on subjects before and after subcutaneous injection of these drugs at two different ambient temperatures.

CONCLUSIONS

Changes in evaporative rate produced by these drugs are thermally compensated by alterations in convection and radiation and, under some conditions, in peripheral blood flow and metabolism. The compensatory mechanisms are not sufficiently prompt nor large enough to maintain thermal balance immediately after the injection. They persist, however, much longer than does the altered evaporative rate. The "atropine flush" is a reaction secondary to a reduction in evaporative rate.

RECOMMENDATIONS

None.

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I. INTRODUCTION

The administration of atropine inhibits, and pilocarpine increases, sweat secretion (1, 2). Since sweat secretion is an important regulator of heat loss (3, 4, 5), any change in sweat rate, if uncompensated, should produce a change in body heat content. It was of interest, therefore, to determine the manner and extent of compensation to the thermal stresses imposed by the administration of these drugs.

Since sweat rate is influenced by the ambient temperature, it was desirable to determine whether or not the thermal effects of these drugs are altered by varying the environmental temperature. Sweating at 29°C. is normally minimal or absent (6), while in an ambient temperature of 38°C., evaporation is the only route of heat loss.

II. EXPERIMENTAL

A. Apparatus and Methods

The method of human calorimetry used here is the same as that employed previously at this laboratory (7). The subject lay on a waterproof netting in a ventilated chamber and breathed into a closed circuit metabolism apparatus. Evaporative rate was recorded continuously by an infrared gas analyzer (8). Air, wall, rectal and skin temperatures were measured by thermocouples (9). Each of two subjects received 1 mg. atropine sulfate subcutaneously at ambient temperatures of 29° and 38°C., and each of two other subjects received 10 mg. pilocarpine hydrochloride by the same route at the same temperatures.

In 4 of the 8 runs, the subjects reported in a postabsorptive state; in the remainder they had eaten breakfast. After disrobing they rested for one-half hour before entering the calorimeter. Control observations were then made until all measurements seemed to reach constant values (1 to 2 hours), whereupon the injection was given. Following the injection, measurements were continued until they approached the control values (1 to 4 hours). A complete thermal balance was calculated for each experiment; peripheral blood flow was obtained from the thermal data by the method of Hardy and Soderstrom (6).

B. Results

The results shown in Figures 1 and 2 are plotted as average values for 12 minute periods and the vertical broken lines indicate the times of injection. No essential difference was found in the results on basal and nonbasal subjects. One graph of each pilocarpine and atropine run at 38°C. is shown as representative of the data obtained;

although the magnitude of the individual thermal responses differed in duplicate runs, the essential pattern of compensatory reactions was the same.

1. Pilocarpine.

a. Ambient temperature 38°C. (Figure 1).

Almost immediately after the injection the evaporative rate rose rapidly, reached a peak in 12 to 24 minutes, and returned to normal values 48 to 60 minutes post injection. As a result of the increased evaporative cooling, skin temperature fell markedly. The fall in skin temperature increased heat gain by convection and radiation. A small increase in heat gain was also obtained by a rise in the metabolic rate due to shivering. Peripheral blood flow was decreased, preventing heat loss from the deep tissues. As a resultant of all changes the heat content of the body fell, reaching a minimum about one-half hour after injection and returning slowly to the control value thereafter. There was a fall in rectal temperature which was slower and smaller than that of the skin.

b. Ambient temperature 29°C.

The pattern of changes observed at this temperature was the same as that at 38°C., except that peripheral blood flow was not reduced significantly. This difference is explained by the fact that peripheral blood flow values were minimal before the injection.

2. Atropine.

a. Ambient temperature 38°C. (Figure 2).

Following the injection evaporation fell rapidly, reaching a minimum value 12 to 24 minutes after injection, and returned to normal in 36 to 60 minutes post injection. As a result of the decreased evaporative cooling, skin temperature rose and this, in turn, reduced heat gain by convection and radiation. Peripheral blood flow showed a very striking increase which aided dissipation of heat from the deep tissues. No change was observed in metabolism. As a resultant of all changes, the heat content of the body rose, reaching a maximum 48 minutes after injection and falling slowly thereafter. There was a rise in rectal temperature which was slower and smaller than that of the skin. Marked flushing was observed 20 minutes after injection and persisted for about 2 hours.

b. Ambient temperature 29°C.

No significant thermal changes were produced by the injection. This is explained by the fact that there was no active sweating during the control period. No flushing was observed.

III. SUMMARY AND CONCLUSIONS

The primary thermal effect of the subcutaneous injection of atropine and pilocarpine is a change in evaporative rate. The resulting change in skin temperature brings about alterations in convection and radiation which thermally oppose the change in evaporative rate. Changes in peripheral blood flow and metabolism, if present, also counteract the initial effect. The compensatory mechanisms are not sufficiently prompt nor large enough to maintain thermal balance immediately after the injection. They persist, however, much longer than does the altered sweat rate. Since flushing of the skin after injection of atropine occurred only at the higher ambient temperature, it is concluded that the "atropine flush" is a reaction secondary to a reduction in evaporative rate.

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FIG I PILOCARPINE 38°C

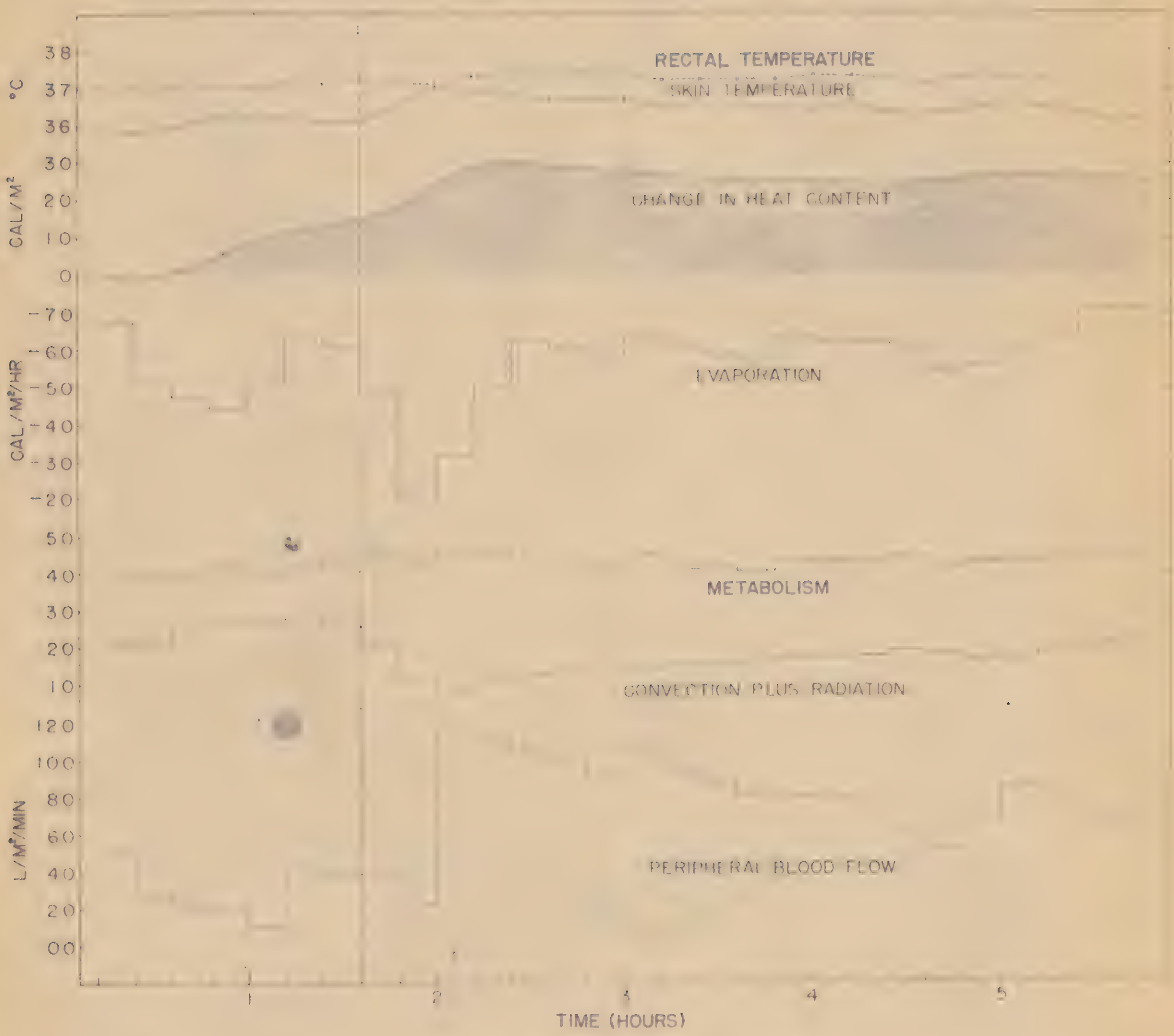

FIG. 2 ATROPINE 38°C

AN ANALYSIS OF CEREBRAL CONTROL OF REFLEX PUPILLARY DILATATION IN THE CAT*

by

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15 July 1948

*Sub-project under Study of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946. MDFRL Project No. 6-64-12-06-(9).

No. 5

Project No. 6-64-12-06
Sub-project MDFRL 06-(9)
MEDEA

15 July 1948

ABSTRACT

AN ANALYSIS OF CEREBRAL CONTROL OF REFLEX PUPILLARY DILATATION IN THE CAT

OBJECT

The objects of this project were to determine (1) whether the sympathetic and/or parasympathetic systems are active in controlling reflex pupillary dilatation following cerebral excitation, (2) the course which the reflex pathways follow, and (3) the degree of activity of the pupillary light reflex during stimulation of cerebral pupillodilator areas.

RESULTS

In fourteen experiments following excitation of the gyri proeus, genualis and subcallosus, a bilateral 2-5 mm. reflex pupillary dilatation occurred due to inhibition of parasympathetic activity. Hypothalamic stimulation caused a 6-8 mm. reflex mydriasis due to sympathetic activity. Evidence suggests that the reflex fibers originating in the gyri proeus, genualis and subcallosus pass through the hypothalamus to the Edinger-Westphal nucleus.

The light reflex was abolished during the excitation of the cerebral pupillodilator areas but reappeared following the disappearance of the pupillary dilatation.

CONCLUSIONS

1. Cerebral reflex pupillary dilatation in cats follows adequate excitation of the gyri proeus, genualis and subcallosus.

2. Cerebral reflex pupillary dilatation is due to active inhibition of parasympathetic activity. No sympathetic component was demonstrated.

3. Evidence suggests that centrifugal frontal lobe fibers controlling reflex pupillary dilatation by active inhibition of parasympathetic activity pass through the hypothalamus to the Edinger-Westphal nucleus.

4. The light reflex is abolished during excitation of the cerebral reflex pupillodilator areas.

RECOMMENDATIONS

None.

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AN ANALYSIS OF CEREBRAL CONTROL OF REFLEX PUPILLARY DILATATION IN THE CAT

I. INTRODUCTION

Pupillary dilatation in animals following cerebral electrical stimulation has been reported by several early workers (1,2,3,4,11,15). In 1900, Sherrington's work on dogs demonstrated that pupillary dilatation following cerebral excitation was due to inhibition of parasympathetic activity (16). Succeeding work on cats and dogs has substantiated his observations (5,6,13,17,18). However, Karplus and Kreidl reported the existence of a sympathetic subcortical pupillodilator center in the cat's tuber cinereum under control of the orbital gyrus (10).

The purpose of this project was to determine (1) whether the sympathetic and/or parasympathetic systems are active in controlling reflex pupillary dilatation following cerebral excitation, (2) the course which the reflex pathways follow, and (3) the degree of activity of the pupillary light reflex during stimulation of cerebral pupillodilator areas.

The pathogenesis of anisocoria following cerebral trauma is controversial. Hutchinson was the first to describe the dilated, fixed pupil resulting from oculomotor nerve impingement in patients (7,8). The majority of cases with anisocoria have since been explained by this mechanism (9,12,14). However, it has recently been shown that in two thirds of a large series of head trauma cases the ipsilateral dilated pupil reacted well to light, subsequent autopsy examinations revealed no oculomotor nerve impingement, and other observations suggested a cerebral control of pupillary activity (20). Since the majority of the above cases had associated cerebral hematomas, additional experiments are in progress in which the effects of such experimentally induced lesions in animals are being studied in relation to the correlation of cerebral and oculomotor nerve compression with the degree of anisocoria and light reflex activity. It is hoped that such work, together with the present communication, will lay the ground work, for clarification of the mechanism producing ipsilateral pupillary dilatation in the presence of a normal light reflex.

II. EXPERIMENTAL

A. Apparatus and Methods

1. Sacrifice experiments were performed on fourteen cats. Each animal was anesthetized with sodium pentobarbital injected intraperitoneally in amounts ranging between 35-45 mgm./kilo. The right cerebrum was exposed and the head fixed to a Horsley-Clarke apparatus modified to the extent that the instrument was bolted to the table and could be adjusted in the longitudinal axis of the table by means of an eccentric cam (see Figures 1 and 2). From this apparatus a bipolar concentric needle electrode delivered one-second bursts of sixty cycle current at 3-6 volts at millimeter intervals throughout the anterior three-quarters of the right cerebrum. The pupillary responses were observed through a lens at a magnification of two times and recorded as mild (2-3 mm.), moderate (3-5 mm.), and marked

(5-6 mm.). The course of each experiment extended over a 14-16 hour period. The brains were perfused in vivo with 10 per cent formalin U.S.P., and preserved for a week. The brains were then embedded in paraffin and serial coronal sections made at 10 μ thickness. Every tenth section was stained by the Weil technique. The anatomical structures involved were projected on millimeter paper, identified and correlated with pupillary responses.

2. To determine which portion of the autonomic nervous system participated in cerebral control of reflex pupillary dilatation, selective nerve sections were made. Right superior cervical sympathectomies were made on two cats, followed by a thorough cerebral exploration. Removal of sympathetic activity permitted observations to be made on the intact and sympathectomized pupil following excitation of the frontal lobe. One cat, in addition to a right cervical sympathectomy, had a right ciliary ganglionectomy. The denervated pupil's function was compared to that of the intact pupil following routine stimulation. In addition, the sympathectomized pupil was compared with the intact pupil during stimulation of the hypothalamus which is the origin of sympathetic activity.

3. The course which the reflex fibers follow was demonstrated upon hypothalamic excitation in preparations with right superior cervical sympathectomies.

4. Light reflex activity was tested by shining 100 foot-candles of light into the left pupil simultaneously with each cerebral stimulus.

B. Results

1. Stimulation of Pupilloexcitatory Areas

The results of a representative experiment shown in Figure 3 demonstrate the location of the cerebral pupilloexcitatory areas. In all experiments the responsive areas were limited to the gyri proeus, genualis and subcallosus. When excited, a mild to moderate bilateral dilatation occurred. The duration of a typical response is seen in Figure 4 (dotted line curve); the extent of dilatation is shown in Figure 5. The result of hypothalamic stimulation was a marked bilateral mydriasis accompanied by activity of the nictitating membrane, piloerection, and baring of the foreclaws. In the latter, the latent period was not discernible (see Figure 4, broken line curve).

2. Nerve Section

Selective nerve sections were made to demonstrate whether cerebral excitation activated the pupil reflexly through the sympathetic or parasympathetic system.

Right superior cervical sympathectomies were made on two cats. The subsequent excitation of the gyri proeus, genualis and subcallosus still caused a normal pupillary response as shown in the dotted line curve in Figure 4. However, in the same preparation following hypothalamic stimulation, in addition to the overt sympathetic response mentioned above, the sympathectomized pupil followed the course shown by the broken line in

Figure 4. Subsequent intravenous injection of 0.5 cc. of 1:1000 adrenalin caused bilateral maximal pupillary dilatation for three minutes followed by slow contraction. This showed that the pupils were still functional.

A right superior cervical sympathectomy and ciliary ganglionectomy were performed on one cat. The denervated pupil assumed the constricted size seen in Figure 6, and remained so throughout the following fourteen hours in spite of the stimulation of the cerebral reflex pupillo-excitatory areas. The left pupil reacted normally as seen in Figure 5. Again intravenous injection of 0.5 cc. of 1:1000 adrenalin caused a prolonged bilateral mydriasis similar to that in the sympathectomized preparations.

3. The Light Reflex

The light reflex was always abolished during the excitation of the cerebral pupillodilator areas. The reflex reappeared immediately following the disappearance of the pupillary dilatation.

III. DISCUSSION

The experiments substantiate the existence of cerebral reflex pupillodilator areas which function by inhibition of parasympathetic activity as shown by Magown et al. (6). They also show that the excitatory areas are restricted to the gyri proeus, genualis and subcallosus. These areas lie first superior and anteromedially and then descend caudally to the hypothalamus (see Figure 3). The subsequent passage of these reflex fibers through the hypothalamus was demonstrated in preparations with a right superior cervical sympathectomy. Following hypothalamic stimulation the sympathectomized pupil dilated slowly to 4 mm. (see dotted line in Figure 4), whereas the intact left pupil responded by rapid maximal dilatation accompanied by other overt sympathetic activity (see broken line in Figure 4). The sympathectomized pupillary reaction demonstrating the existence of projections from the gyri proeus and genualis in the hypothalamus is present but hidden by the more dominant sympathetic pupillary dilatation in preparations with bilaterally intact pupils.

The pupillodilator control over the tuber cinereum reported by Karplus and Kreidl to lie in the orbital gyrus could not be demonstrated. However, Ward and Reed reported areas 8 to contain a sympathetic pupillodilator center in monkeys (19). It is possible that the cerebral sympathetic control over the pupil becomes dominant as the animal scale is ascended.

The consistent abolition of the light reflex is to be expected during excitation of cerebral pupillodilator areas with subsequent inhibition of the Edinger-Westphal nucleus since the origin of the efferent arc of the light reflex pathway is located in this nucleus.

IV. CONCLUSIONS

1. Cerebral reflex pupillary dilatation in cats follows adequate excitation of the gyri proeus, genualis and subcallosus.

2. Cerebral reflex pupillary dilatation is due to active inhibition of parasympathetic activity. No sympathetic component was demonstrated.

3. Evidence indicates that centrifugal frontal lobe fibers controlling reflex pupillary dilatation by active inhibition of parasympathetic activity pass through the hypothalamus to the Edinger-Westphal nucleus.

4. The light reflex is abolished during excitation of the cerebral reflex pupillodilator areas.

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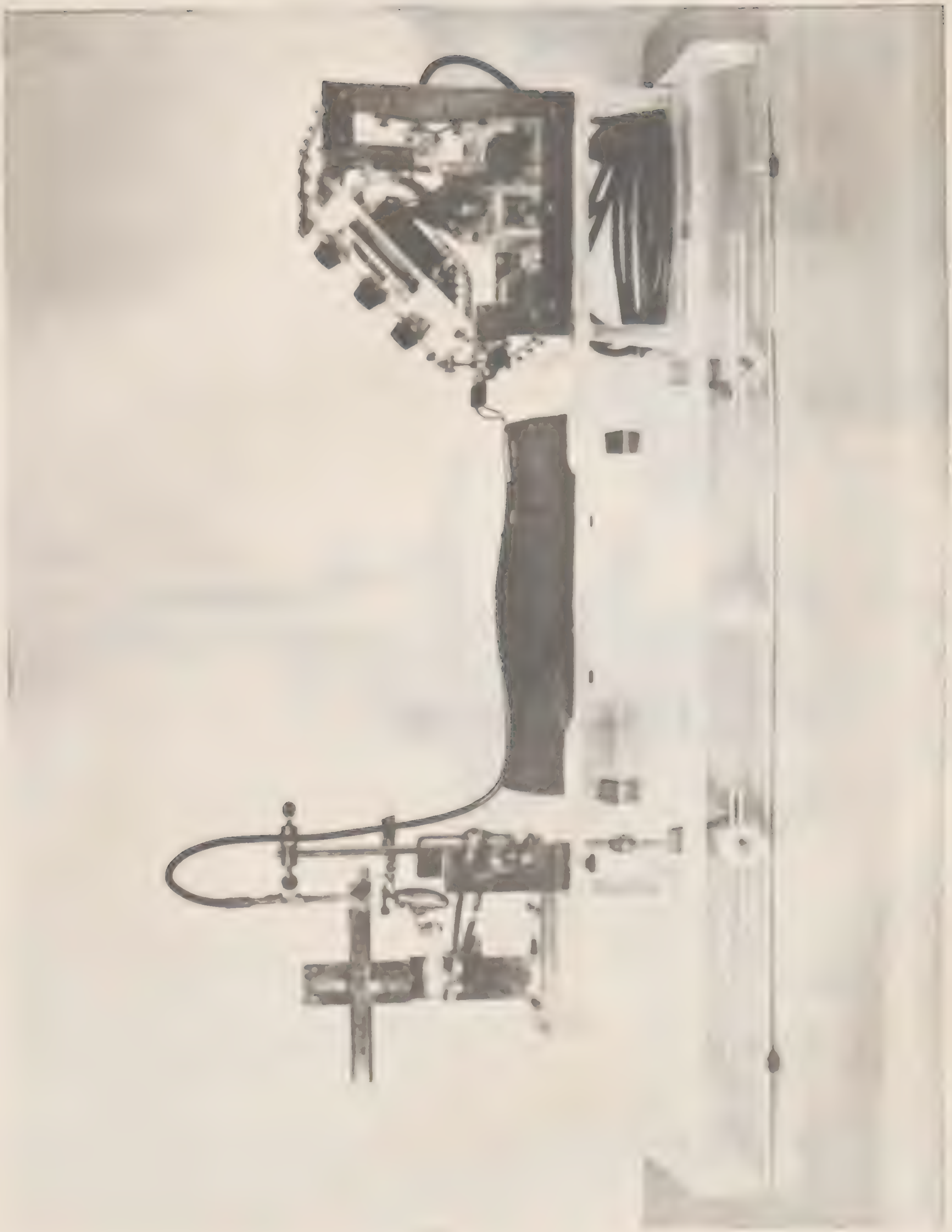


FIG. 1

FIG. 2

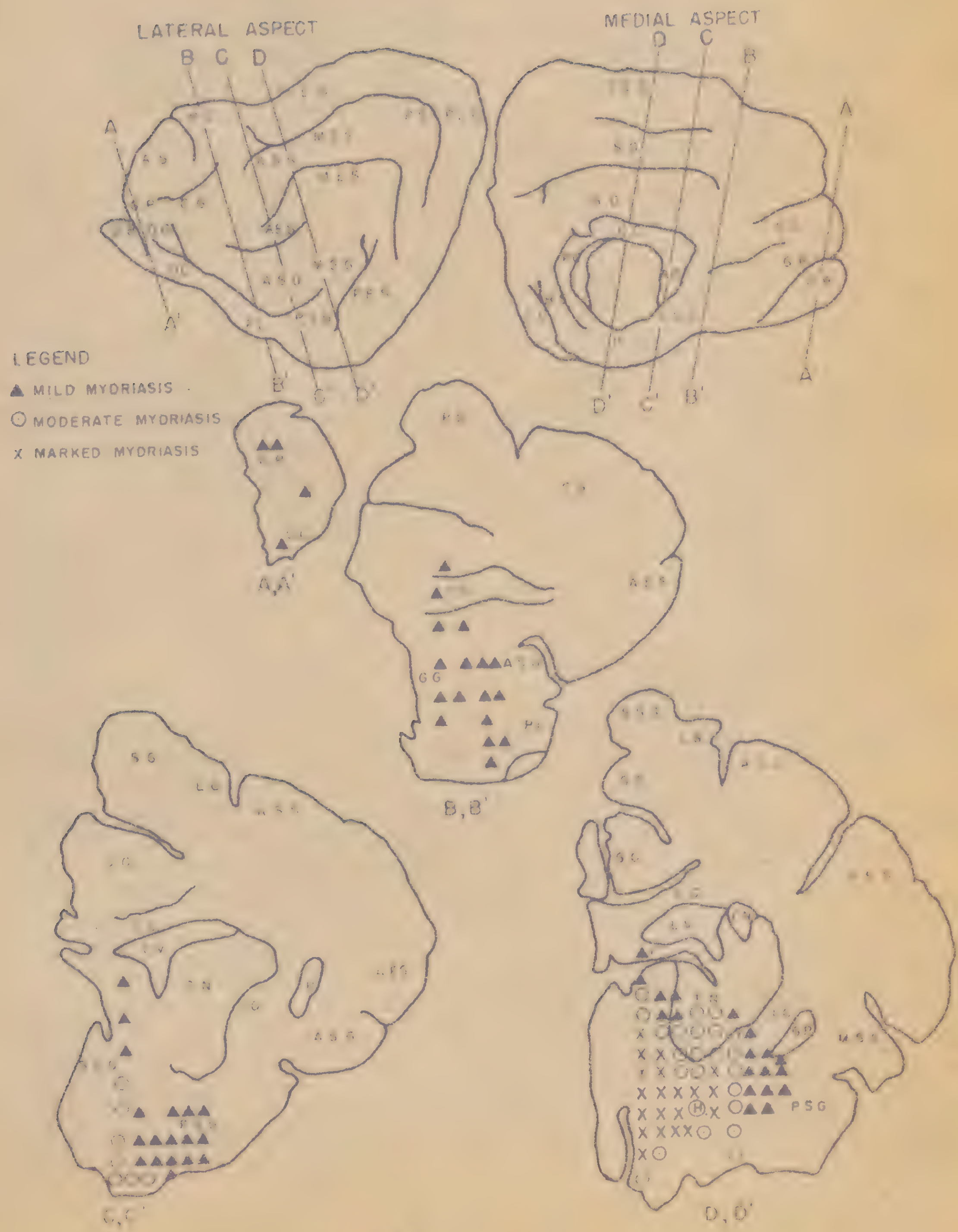
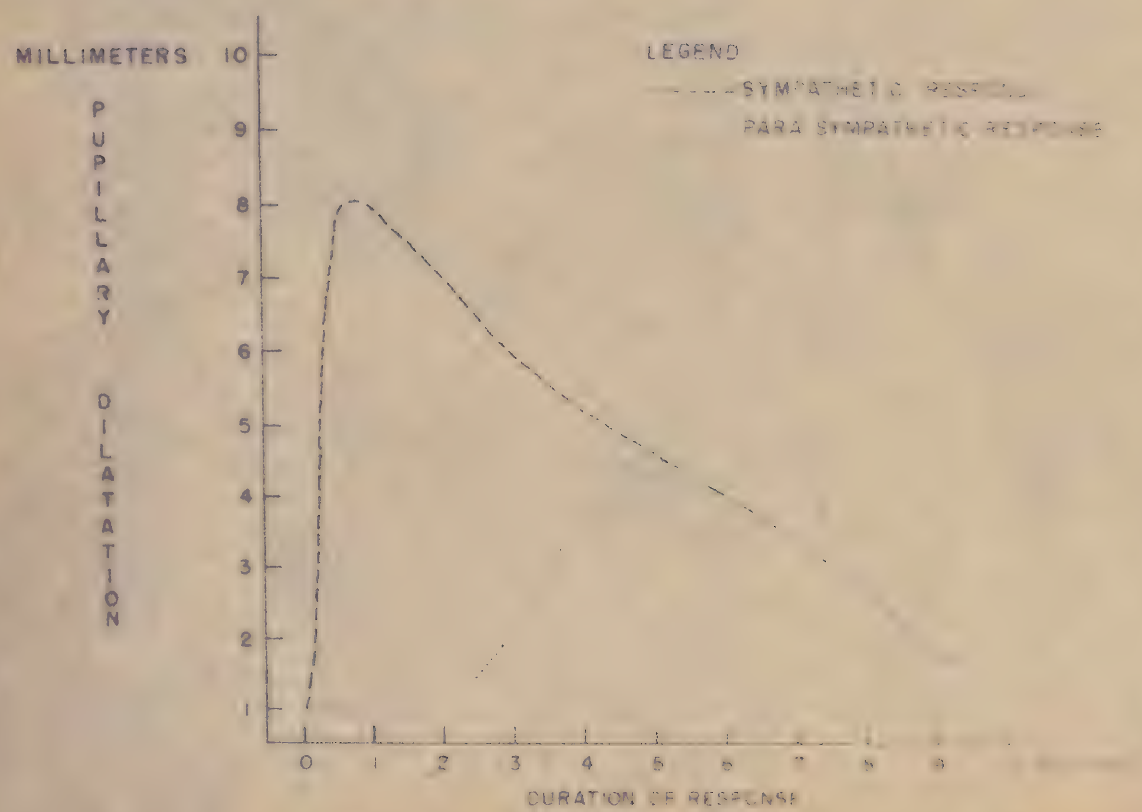

LATERAL ASPECT
MEDIAL ASPECT
LEGEND
▲ MILD MYDRIASIS
○ MODERATE MYDRIASIS
X MARKED MYDRIASIS
A,A'
B,B'
C,C'
D,D'
PSG

FIG. 3

KEY FOR FIGURE 3

A.C.	Anterior commissure
A.E.S.	Anterior ectosylvian gyrus
A.S.	Anterior sigmoid gyrus
A.S.G.	Anterior sylvian gyrus
A.S.S.	Anterior suprasylvian gyrus
C.C.	Corpus callosum
C.G.	Coronal gyrus
C.N.	Caudate nucleus
D.G.	Dentate gyrus
F.	Fornix
F.G.	Fusiform gyrus
G.C.	Gyrus cinguli
G.G.	Gyrus genualis
G.P.	Gyrus Proeus
H.	Hypothalamus
H.G.	Hippocampal gyrus
I.C.	Internal capsule
L.G.	Lateral gyrus
L.O.T.	Lateral olfactory tract
L.B.	Lateral ventricle
M.E.S.	Middle ectosylvian gyrus
M.S.G.	Middle sylvian gyrus
M.S.S.	Middle suprasylvian gyrus
O.B.	Olfactory bulb
O.C.	Olfactory crus
O.G.	Orbital gyrus
P.	Putamen
P.E.S.	Posterior ectosylvian gyrus
P.L.	Pyriform lobe
P.L.G.	Posterior lateral gyrus
P.S.	Posterior sigmoid gyrus
P.S.G.	Posterior sylvian gyrus
P.S.S.	Posterior suprasylvian gyrus
S.C.G.	Subcallosal gyrus
S.G.	Splenial gyrus
S.S.G.	Suprasplenial gyrus
T.N.	Thalamic nucleus



THE BROKEN LINE [illegible] RESPONSE FOLLOWING HYPOTHALAMIC EXCITATION. THE [illegible] THE SYMPATHECTOMIZED [illegible] INTACT PREPARATIONS

FIG. 4

FIG. 5

FIG. 6

THE REGULATION OF BODY TEMPERATURE DURING FEVER*

by

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1 October 1948

*Sub-project under Study of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946. MDFRL Project No. 6-64-12-06-(6).

No. 6

Project No. 6-64-12-06
Sub-project MDFRL 06-(6)
MEDEA

1 October 1948

ABSTRACT

THE REGULATION OF BODY TEMPERATURE DURING FEVER

OBJECT

Fever in man was studied calorimetrically to determine, first, the heat flows which cause changes in body temperature and, second, the physiological regulations which directly control these flows. Seventeen reactions induced by typhoid vaccine were observed in environments ranging in ambient temperature from 27° to 43°C.

RESULTS AND CONCLUSIONS

Changes in body temperature are due almost entirely to autonomic regulation of peripheral blood flow, sweat secretion, and muscular activity. Peripheral blood flow, by altering the skin temperature, is a control of heat exchange by convection and radiation; sweating is a control of evaporative cooling; and muscular activity, in the form of shaking chills, controls metabolic heat production. Sweating and muscular activity secondarily cause changes in convection and radiation. These changes are opposed to the primary thermal effects of sweat secretion and chills but are smaller in magnitude.

The pattern of temperature regulation in fever is governed by the thermal nature of the environment and the strength of the pyrogenic stimulus. Whenever possible, temperature changes are brought about by altering the rate of heat loss from the body rather than by changing the rate of heat production.

To raise the body temperature, heat production can be increased, heat loss restricted, or both changes can be induced.

Peripheral blood flow and sweating must be restricted in order to maintain a normal body temperature in a cool environment. Since heat loss cannot be reduced appreciably a febrile rise can be accomplished only by increasing heat production, i.e., by muscular activity, and the degree of fever will be proportional to the severity of the chill. When the environment is warm (above 30°C.), fever can be produced by decreasing heat loss, i.e., restriction of peripheral blood flow and sweat secretion. Unless the environment is very hot, however, only gradual temperature rises can be effected. If the pyrogenic stimulus demands a sharp rise in temperature, a chill is superimposed on restricted heat loss even in very hot environments.

The lysis of fever may be a passive or an active process. Passive cooling occurs when there is no increase in peripheral blood flow or sweat secretion. The skin temperature is elevated at the height of fever

and the greater loss of heat by convection and radiation exceeds heat production. Passive cooling can occur only in a cool environment after fever induced by a chill, or after a fall in environmental temperature. When peripheral blood flow and/or sweating increases, as is usually the case, cooling is active. Active cooling is necessary in hot environments, or to produce rapid defervescence in cooler surroundings.

RECOMMENDATIONS

None.

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THE REGULATION OF BODY TEMPERATURE DURING FEVER

I. INTRODUCTION

A change in the temperature, or heat content, of man is produced by an imbalance between the rates of gain and loss of heat by the body. The magnitude of change depends on the degree of imbalance and the time for which it persists, as expressed in the equation:

$$\triangle H = (M + E + C + R)\ t$$

where $\triangle H$ = the change in body heat content
M = the rate of heat production by metabolism
E = the rate of cooling by evaporation
C = the rate of heat exchange with the ambient air by convection
R = the rate of heat exchange with the surfaces of the environment by radiation
t = time

If, in this equation, heat gains are considered positive and heat losses negative, metabolism will always be a positive rate, evaporation a negative rate, while convection and radiation will be positive if the environmental temperature is above that of the skin and negative if the ambient temperature is below the skin temperature.

In this report, a description is given of the changes in the flow of heat between man and his environment which occur in the production and lysis of fever. Some of the physiological regulations directly concerned in the control of these flows are discussed.

Thermal balance during fever has been studied most extensively at the Russell Sage Institute in New York, and the findings of these and previous investigators have been reviewed by Du Bois (1,2,3). It was shown that fever could be produced by an increase in metabolic heat production if a shaking chill occurred. Defervescence was caused by a rise in the rate of cooling, chiefly by evaporation. In the present study, among the many further aspects of temperature regulation in fever, the following questions received particular attention. What are the patterns of thermal exchange and regulation in the more commonly observed type of febrile reaction in which no chill occurs? What effect does the thermal nature of the environment have on the pattern of febrile reaction? (In this regard, it should be noted that heat exchanges by convection and radiation depend as much on the thermal properties of the environment as on the temperature of the skin. The wind velocity and relative humidity affect the rate of cooling by evaporation and it has been postulated that the metabolic rate may be affected by the environmental temperature. Thus, it might be expected that a different pattern of heat exchange and regulation would be seen in warm and hot environments when compared to the cool environments in which all previous studies have been carried out.) Finally, what are the autonomic physiological regulations which directly influence thermal flows in fever? Thus convection and radiation are

partial functions of the skin temperature which, in turn, is in part a function of the peripheral blood flow*. Evaporative cooling is dependent to a considerable degree on the rate of sweating, pulmonary ventilation, and other physiological factors. Metabolism is largely regulated by muscular activity but a "chemical regulation," that is, a controlled change in heat production without a change in muscular movement, has been postulated (4) and may be operative in fever.

Fever can be defined at present only in terms of the level of body temperature and, since the rectal and skin temperatures can vary over a considerable range under normal circumstances, any definition is necessarily arbitrary and inexact. In these studies, the experimental conditions were so controlled that fever was defined as any rise in rectal temperature greater than 0.2°C. or any rise in body heat content of more than 10 Calories per square meter of body surface.

II. EXPERIMENTAL

A. Methods and Procedures

Ten young soldiers volunteered as subjects. Each was studied in a constant environment during one control and two fever experiments. The data obtained in the control studies were used as base line values for comparison with measurements made during febrile reactions following the intravenous injection of U. S. Army triple typhoid vaccine.

A new method of human calorimetry was employed, details of which have been presented separately (7). The nude subject was observed for a period of 4 to 8 hours while reclining on a netting in the closely regulated environment of a small experimental chamber. The air temperature and wall (radiant) temperatures inside the chamber were held at essentially the same constant values throughout a given run. Different environments were created from one experiment to the next over the temperature range from 27° to 43°C. The wind velocity was constant at 15 ft./min. (equivalent to a well-ventilated but not windy room), and the humidity was always low (vapor pressure of water, 7-12 mm. Hg).

A constant flow of air was maintained over the subject, and evaporation was measured continuously and nearly instantaneously by a special modification of an N.D.R.C. infra-red gas analyzer (8) which recorded directly the difference between the water vapor concentrations at the inlet and outlet of the chamber. Oxygen consumption was measured by an adaptation of a closed circuit system (7), and heat production was computed therefrom as a continuous series of average values, each of which was based on the time required for the utilization of 2.5 liters of oxygen.

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* The term "peripheral blood flow" refers throughout this report to the flow of blood through the outermost tissues of the body to the depth of 2 cm. (5, 6).

Rectal, skin (9), and environmental temperatures were determined by thermocouples at 15-minute intervals, and the mean skin temperature was calculated by weighting each of the 10 skin readings by the fraction of body surface represented (7). Peripheral blood flow was computed from the calorimetric values by the procedure of Hardy and Soderstrom (6).

B. Results

All results have been calculated and graphed in the same way. In each graph (Figures 1 through 6) the rectal and mean skin temperatures are shown in the top panel with the scale on the right. The cumulative change in heat content of the body, ΔH, appears in the same panel as a shaded area with the scale on the left. The rates of heat flow are shown in the middle three panels. Metabolism, radiation, and convection are plotted as average values for intervals of fifteen minutes or less. Evaporation is shown by two smooth curves, the upper of which is total evaporation and the lower from the skin only. The separation of the lines indicates the rate of vaporization from the lungs. Peripheral blood flow was calculated for successive fifteen-minute intervals.

1. Control Experiments. A description of certain features of thermal regulation in the resting normal subject is necessary for an appreciation of the changes which occur during fever. The experiment in an environment of 29°C., shown in Figure 1, illustrates several of these characteristics which were common to all control runs.

A slow fall in rectal temperature, skin temperature, and heat content occurred during the first three hours. Such a fall was a consistent finding* in all environments and was often two or three times larger than shown here. In the last hours of this run a rise of 0.2°C. in rectal temperature and 8 Calories per square meter of body surface in heat content was measured and, since this was the largest rise in any control run, it was taken as the arbitrary limit separating normal and febrile reactions. Fluctuations in metabolic rate of about the magnitude shown here were seen in all subjects. They could not be correlated with any visible changes in muscular activity and may reflect in part instrumental error. Heat exchanges by convection and radiation paralleled each other since both were nearly equivalent functions of the difference between the environmental and mean skin temperatures. Evaporation from the skin fluctuated irregularly during the first three hours. This was the characteristic pattern of evaporation when sweating was active and probably reflected closely the irregular rate of sweat secretion from the body as a whole, since water was evaporated very rapidly at all times. With heavy sweating, variations in rate were more pronounced. During the last three hours, evaporation fell to a constant level. A low, flat tracing of this

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* In subsequent unpublished studies in which subjects in the basal state were employed, this fall was less or absent. It seems probable that the physiological thermostat slowly adjusts to a lower level of body temperature with the cessation of physical activity and the decline in specific dynamic action.

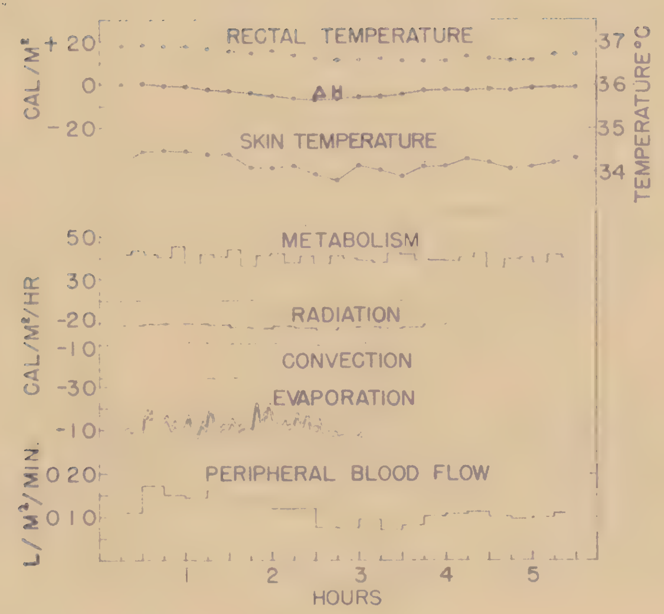

FIG. 1. THE TEMPERATURE, HEAT EXCHANGES, AND PERIPHERAL BLOOD FLOW OF A NUDE MAN IN AN ENVIRONMENT OF 29°C. SUBJECT III.

type was typical of "insensible water loss" when sweating was absent and the only water vaporized was that diffusing through the skin. Evaporation from the lungs did not change since there was no change in pulmonary ventilation.

The range of experimental conditions and calorimetric values have been summarized for all control experiments in Table I. There was no correlation between the rectal and environmental temperatures, and only slight tendency for the skin temperature to be higher in the heat. Metabolism was only mildly influenced by the ambient temperature, although the subjects felt close to shivering after several hours in the coolest environments and were uncomfortably warm in the hottest environment. Heat exchanges by convection, radiation, and evaporation were greatly altered by changes in the environment. Convection and radiation, which were paths of heat loss in the cool, became routes of gain in the heat. In cool environments with subjects I, II, and III evaporation was near the level of invisible water loss, but in hot environments, with subjects IX and X, the rates of sweat secretion averaged more than 300 grams per hour. Peripheral blood flow tended to be higher in the heat.

The autonomic physiological mechanisms for temperature regulation were apparently adequate throughout this range of environmental conditions. This was suggested, first, by the fact that the rectal temperature was not influenced by environmental differences, and second, the fall in heat content was as great in the hot environments as in the cool ones. The mechanisms for temperature control proved to be similar in the normal and febrile state differing only in degree and in temperature relations.

2. Fever Experiments. These studies of febrile reactions have been grouped according to the environmental temperature, beginning with the experiments at 27-29°C. and ending with the experiments at 43°C. Each run has been subdivided into arbitrary periods based on the upward or downward trend of the change in body heat content. Control periods are not included in the charts. Typhoid vaccine was injected 15 minutes before the first experimental point on each graph.

a. Environmental Temperature 27-29°C. When the environment is sufficiently cool, all channels of heat loss from the body are reduced essentially to absolutely minimal levels to conserve body heat. In such circumstances a febrile rise in temperature, even if it is slight, can only be induced by an increase in heat production. In our experience, such an increase must be accomplished by a shaking chill. Situations of this type are approximated in the experiments of Figures 2 and 3.

Of the four febrile reactions studied in this environment, the most severe has been charted in Figure 2. Fifty million organisms were injected intravenously at zero time, and the first measurements were made at 15 minutes. No divergence in the pattern of thermal regulation from that in the control experiments could be noticed during the first or "normal" period lasting for 1 hour, 15 minutes. All thermal exchanges were near the average control level except for evaporation which was slightly

TABLE I

ENVIRONMENTAL CONDITIONS AND AVERAGE CALORIMETRIC VALUES FOR THE CONTROL EXPERIMENTS

SUBJECT	ENVIRONMENT PH_2O = 7-12 mm Hg Wind = 15 ft/min		BODY TEMPERATURE °C		HEAT FLOWS IN CAL/M²/HR				ΔH CAL/M²	PERI-PHERAL FLOW
	Air °C	Wall °C	Rectal	Mean Skin	M	R	C	E		L/M²/Min.
I	27.2	28.9	36.8	33.7	42.2	-22.0	- 9.1	- 11.9	- 4.5	0.08
II	27.8	28.9	36.8	34.8	45.3	-20.1	-10.6	- 15.1	- 6.4	0.25
III	28.9	30.6	36.7	34.2	40.0	-18.4	-10.6	- 11.4	- 3.1	0.14
IV	32.2	32.8	36.8	34.6	40.4	- 7.0	- 3.8	- 33.9	-23.4	0.19
V	32.2	32.9	36.7	35.3	40.5	-11.1	- 7.0	- 23.5	- 7.7	0.39
VI	37.8	37.2	36.9	34.8	45.3	10.9	4.6	- 66.1	- 7.2	0.21
VII	37.8	37.2	36.8	35.6	41.6	7.1	10.7	- 61.3	-13.2	0.52
VIII	37.3	37.8	36.7	34.9	43.8	12.5	2.0	- 68.6	-19.4	0.27
IX	43.3	41.1	37.1	35.8	49.8	25.8	21.7	-101.8	-14.4	0.32
X	43.3	40.6	37.2	34.8	47.0	27.7	20.9	-102.4	-2017	0.44

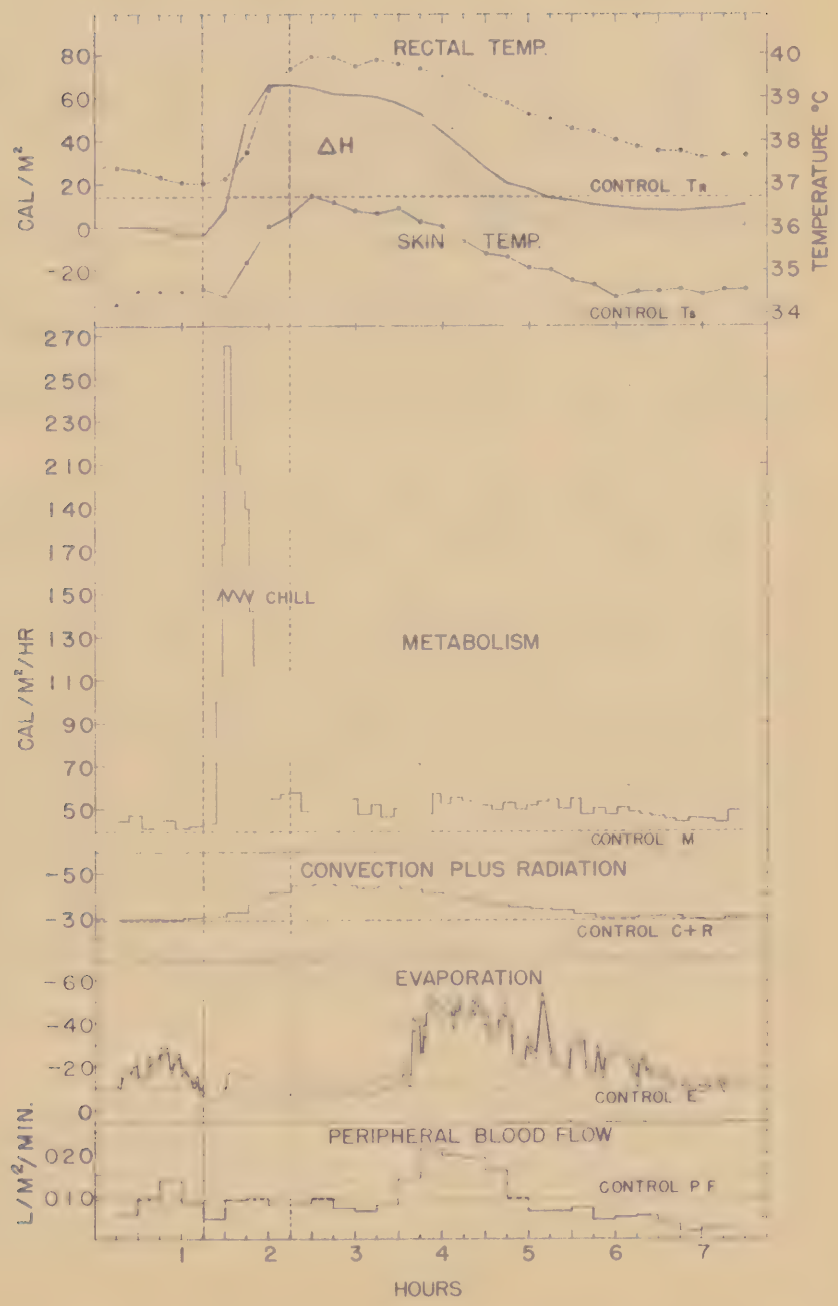

FIG. 2 A SEVER FEBRILE REACTION IN AN ENVIRONMENT OF 29°C. SUBJECT III.

elevated because of low grade active sweating. Total heat loss exceeded gain causing a slight fall in heat content and rectal temperature.

The second period, during which there was a rapid climb in body heat content, lasted from 1 hour 15 minutes to 2 hours 15 minutes. Evaporation had been falling and reached the level of insensible water loss when sweating ceased at the beginning of this period. A few minutes later a severe shaking chill occurred producing a high spike in metabolic heat production. Pronounced hyperventilation reaching 200 liters per minute accompanied the chill, but the increase in pulmonary evaporation was small in relation to other thermal changes. The excess heat production of the chill and the slight restriction of heat loss by evaporation led to a steeply climbing body temperature. In terms of the overall thermal balance, heat gain far exceeded heat loss during this interval, but the rate of heat loss was nevertheless slightly greater than in the "normal" period when temperatures were falling. This greater heat loss was caused by the elevated skin temperature which increased thermal outflow by convection and radiation. This observation is similar to the findings of Barr, Cecil and Du Bois in a comparable environment (10).

The period of falling heat content, beginning at 2 hours and 15 minutes, could be divided into two phases. In the first, lasting to 3 hours and 30 minutes, cooling was passive and the fall in heat content was slow. There was no sweating; peripheral blood flow was low; and cooling by convection and radiation remained above the control level by virtue of the high skin temperature persisting from the previous period. The body lost heat in the same manner as an inanimate object, an analogy suggested by Hardy and Soderstrom in their studies of normal thermal exchanges (6). In the second phase, cooling became active and the fall in heat content was accelerated. Peripheral blood flow increased and, with the onset of sweating, evaporative heat loss rose sharply. Toward the end of the period sweating and peripheral flow were reduced again and, since the skin temperature had now fallen, no further loss in heat content occurred. Throughout the time of falling temperature, heat production was above the base line level. There was no visible muscular movement, the subject felt relaxed and comfortable and the elevated metabolic rate was very probably a function of the elevated body temperature according to van't Hoff's principle (11).

A milder chill and febrile reaction is illustrated by the experiment shown in Figure 3, in which 50 million killed typhoid organisms were injected intravenously. The rise in heat content lasted over a four-hour period and the highest rectal temperature reached was only 38°C. Peripheral blood flow was below the control level on the average and no significant degree of active sweating was measured during the time of rising heat content. Despite these restrictions, the sum of heat losses in this environment very nearly equalled heat gain by metabolism and, up to 2 hours and 45 minutes, the climb in body temperature was very slow. At this time the pyrogenic stimulus apparently necessitated a slightly higher temperature, and a very gentle shaking chill occurred, increasing heat production and accelerating the temperature rise.

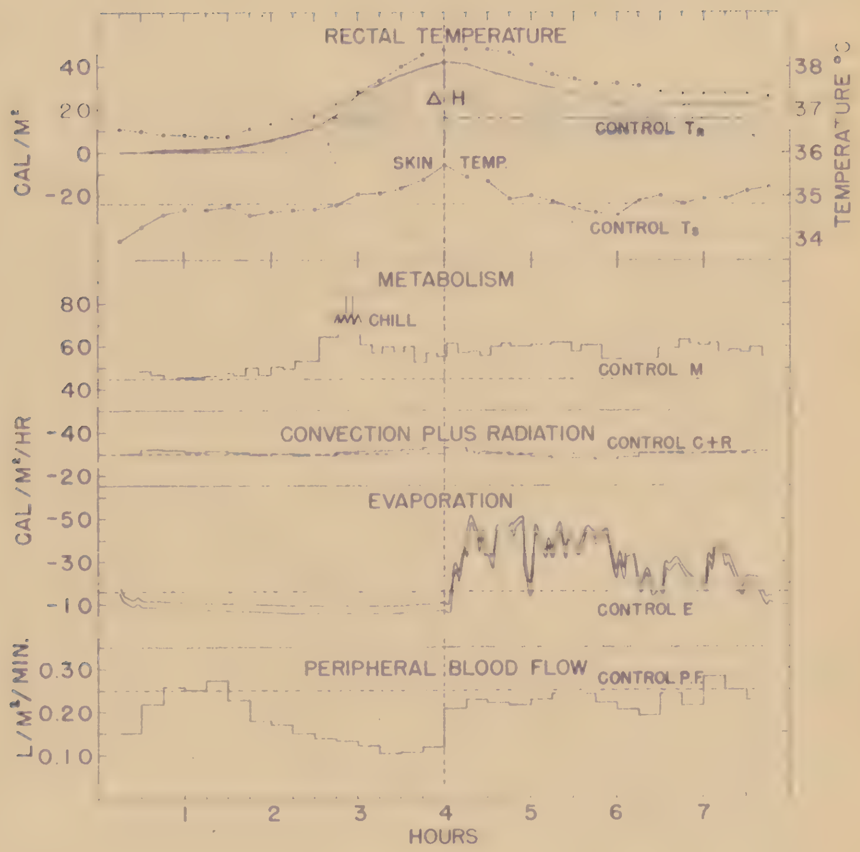

FIG. 3. A MILD FEBRILE REACTION IN AN ENVIRONMENT OF 29°C. SUBJECT II.

There was no phase of passive cooling in this run. Sweating began at 4 hours and was accompanied by a rise in peripheral blood flow. A fall in heat content ensued.

The two other experiments in this environment closely followed the pattern of Figure 3. The environment prohibited effective restriction of heat losses and fevers were induced by shaking chills.

b. Environmental Temperature 32°C. In this warmer environment, the temperature gradient between the body surface and the environment was reduced and, hence, heat loss by convection and radiation was diminished. To maintain a normal temperature, therefore, a compensatory rise in evaporative cooling was necessary, and mild sweating occurred throughout all base line runs.

In the presence of active cooling, the situation was such that a febrile reaction could be produced by restriction of heat losses alone. Such a regulation of the rate of cooling appeared to be responsible for all the changes in heat content in the experiment of Figure 4, which illustrates a mild cyclical reaction to the intravenous injection of 25 million killed typhoid organisms. No chill occurred and the overall changes in heat production were merely secondary to variations in body temperature. From the injection of vaccine at 0 time until 1 1/4 hours, there was no evidence of any disturbance in thermal regulation and a fall in heat content typical of a control experiment took place. At the beginning of the second period sweating ceased, peripheral blood flow reached a low level, and a positive thermal balance was established. The rectal temperature began to climb. Within one half hour, however, peripheral blood flow rose, and within 1 1/4 hours, sweating began again at a low level. Thus it appeared that complete restriction of active cooling caused a response that exceeded the pyrogenic stimulus to the temperature regulating center, and slight cooling was required to slow the reaction. Changes in peripheral blood flow and sweat rate in this experiment occurred at different times and thus appeared to be independent regulatory mechanisms. In the second period, for example, peripheral flow rose at a time when sweating was cut off; in the third period, flow reached a low level while sweating was elevated; and in the fourth period, peripheral flow rose while sweating declined. In other experiments, changes in peripheral flow and sweating rate were nearly synchronous. The differences among the curves of rectal temperature, skin temperature and heat content were marked in this experiment and will be discussed subsequently.

Only mild reactions were obtained in 3 other runs at 32°C. These followed the pattern shown in Figure 4. No chills occurred and body temperature was controlled entirely by regulation of the rate of cooling.

c. Environmental Temperature 3?°C. The most severe reaction studied in this environment has been charted in Figure 5, in which 100 million killed typhoid organisms were injected intravenously. In this instance (fever was produced by a combination of the principal changes described in the earlier experiments) heat elimination was restricted and heat production was increased.

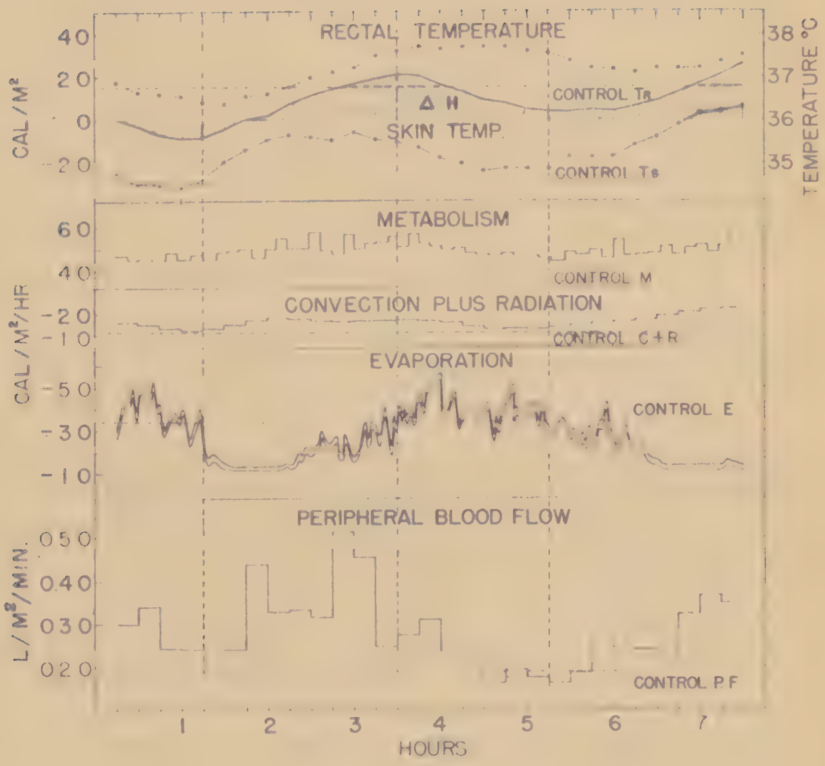

FIG. 4. LOW GRADE CYCLICAL FEVER IN AN ENVIRONMENT OF 32° C. SUBJECT IV.

In the control runs, convection and radiation were positive values because the temperature of the surroundings was above skin temperature. Sweating was marked since evaporation was the only channel for heat loss. Thus a reduction in sweating could cause the retention of large amounts of heat for the genesis of fever.

There was again a 45-minute "normal" period following the injection of vaccine during which time the rectal temperature and heat content fell. Beginning at 45 minutes, sweating and peripheral blood flow were simultaneously and progressively reduced but, before the maximal restriction of heat elimination was reached, a sudden rise in heat production occurred as the result of a shaking chill. A rapid rise of temperature ensued. The elevated skin temperature, however, reduced heat gain by convection and radiation. This effect was thermally equivalent to the increased heat loss noted at the time of rising temperatures in the cool environments (Fig. 2) and, in both instances, the change was thermally opposed to the general trend of temperature regulation. The period of cooling began abruptly at 2 hours, with a rise in peripheral blood flow and the onset of sweating. The wide fluctuations subsequently occurring in evaporation were consistent with the general observation that the sweat rate was much more variable in the febrile than in the normal subject. These fluctuations diminished toward the end of the run as normal body temperatures were approached.

In four other experiments in this environment, the reactions were mild. No chills occurred and temperature control was achieved by regulation of the rate of cooling alone.

d. Environmental Temperature 43°C. The experiment shown in Figure 6 illustrates a severe febrile reaction to the intravenous injection of 100 million killed typhoid organisms in a very hot environment. At the time the typhoid vaccine was administered the subject was slightly febrile as the result of a vaccine injection on the previous day, as evidenced by the initially elevated values of the skin and rectal temperatures. For this reason, also, the first measurements of heat exchanges did not fall close to control lines. The pyrogenic stimulus from the typhoid injection was apparent at 30 minutes when a steep fall in sweat rate and peripheral blood flow* was observed. Although evaporation from the skin was reduced to the level of insensible water loss, a shaking chill occurred in addition and body temperatures climbed rapidly. During this time, the skin temperature exceeded the rectal temperature since heat was gained rapidly at the body surface from the environment by convection and radiation, and evapora-

* The calculation of peripheral blood flow in this period gave negative values that were obviously incorrect. The error arose chiefly from two sources: (1) the rectal and mean skin temperatures are poor indices of average deep and superficial temperatures when these are changing rapidly, and (2) the depth of the thermal gradient arbitrarily assumed for conduction is increased with marked vasoconstriction. It seems, however, permissible to accept the changes in peripheral blood flow as qualitatively significant.

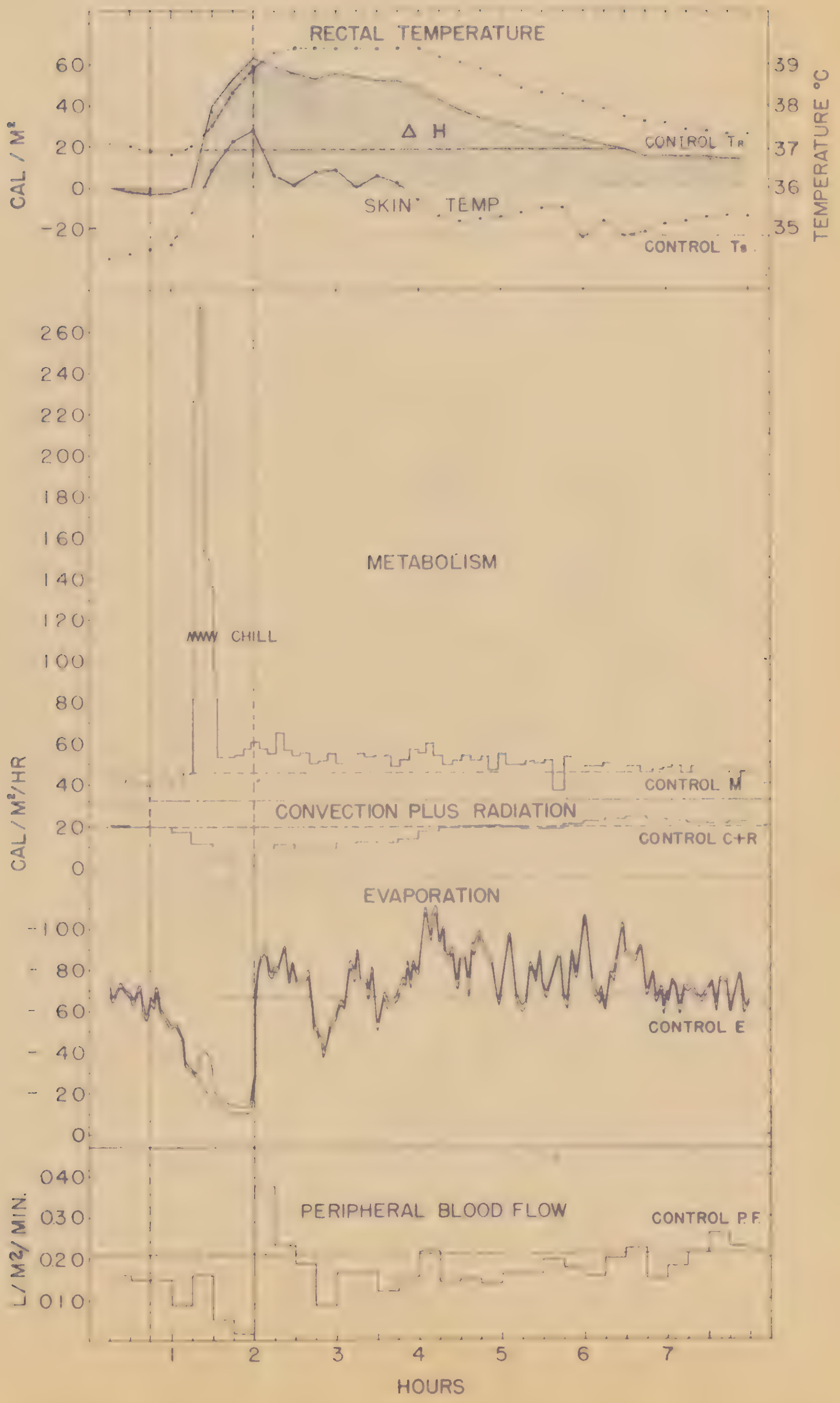

FIG. 5. A SEVERE FEBRILE REACTION IN AN ENVIRONMENT OF 38°C. SUBJECT VI.

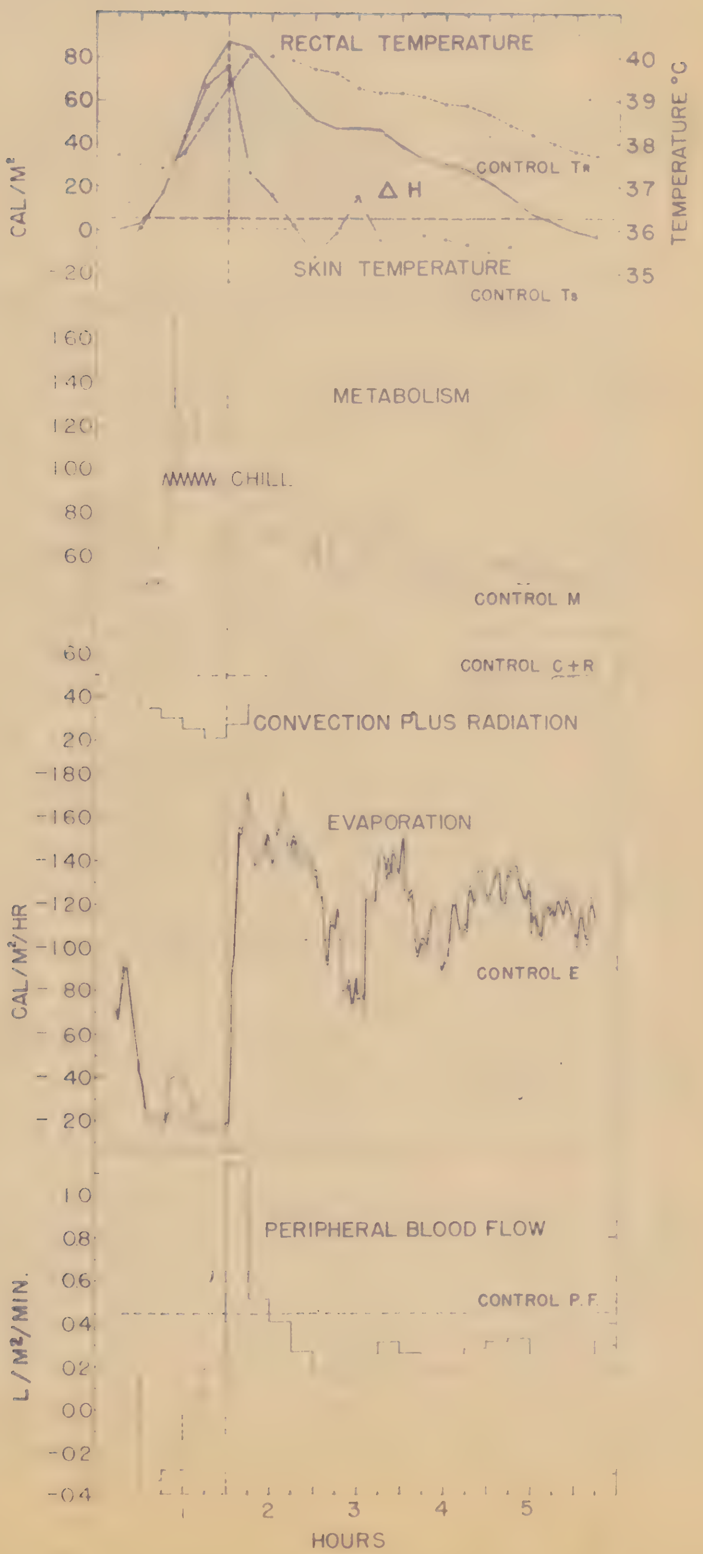

FIG. 6. A SEVERE FEBRILE REACTION IN AN ENVIRONMENT OF 43°C. SUBJECT X.

tive cooling was slight. Defervescence began abruptly at 1 hour and 30 minutes, with a steep rise in peripheral blood flow and the simultaneous onset of sweating. Evaporation reached the rate of 600 gm./hr. within a few minutes.

In two other experiments at 43°C., mild reactions were obtained. These were caused by regulation of the cooling rate. No chills occurred.

III. DISCUSSION

A. Physiological Regulation of Heat Content

Three physiological reactions, muscular activity, sweat secretion, and peripheral blood flow, all functioning autonomically, are the principal controls of body heat content in fever.

Muscular activity is presumably the only mechanism for the regulation of heat production. Theoretically, elevation of heat production can arise from chills, from an increased muscle tonus, or may follow elevations of body temperature according to van't Hoff's law (11). In these experiments, all augmentations of heat production were caused by chills or were secondary to elevations in body temperature. No data were obtained in favor of a "chemical regulation" of the metabolic rate in the febrile or resting subjects.

The rate of sweat secretion is the chief control of evaporative cooling. Evaporation is dependent in part on the wetted area of the body (12) and this, in turn, is a function of the rate of sweat secretion. The environments employed were sufficiently dry to allow rapid evaporation, and the fluctuating tracings obtained indicated closely the pattern of sweat secretion from the body as a whole.

Peripheral blood flow serves as a control of heat exchange by convection and radiation, since it is one of the factors determining skin temperature. A rise in flow increases the transport of heat from the deep tissues to the skin, raises the surface temperature, and alters the thermal gradients for convection and radiation.

In addition, muscular activity and sweat secretion have secondary effects on convection and radiation. A chill raises the deep tissue temperature and, as heat flows to the periphery, the skin temperature rises. Increased sweating allows greater evaporative cooling and, as heat is supplied directly at the body surface, the skin temperature falls. Muscular activity, therefore, promotes heat loss by convection and radiation, and increased sweating promotes heat gain by these routes. The secondary effects on convection and radiation of these regulatory mechanisms are thus opposed to their primary effects but are smaller in magnitude.

The data show that heat exchanges in the resting and the febrile subject fluctuate constantly and often widely. It thus appears that thermal regulation proceeds as a continuous sequence of adjustments, often of

a gross nature, which, however, have little immediate effect on deep tissue temperature because of the large heat capacity of the body and the thermal insulation of the peripheral tissues.

These fluctuations in heat exchanges have an easily seen effect on the skin temperature and, hence, on convection and radiation. From the present data these effects can be presented only in a qualitative manner. Thus in Figure 2, during the time of climbing heat content, the rise in skin temperature and C + R exchange could be ascribed chiefly to the heat production of muscular activity, since only small changes occurred in sweat secretion and peripheral flow. In all charts, gross changes in sweat rate caused inflections in the curves of mean skin temperature. The effect of variations in peripheral flow was usually masked by the secondary effect of muscular activity or sweating, but its important role can be shown in a sample rough calculation. In Figure 5, in the interval from 1 hour and 45 minutes to 2 hours, peripheral flow at a value of 0.02 L/M^2/min. carried 1 Cal/M^2/hr. to the skin. In the succeeding 15 minutes, the flow rose to 0.37 L/M^2/min. and carried 51 Cal/M^2/hr. If the flow had not changed, only 2 Cal/M^2/hr. would have reached the skin in this time; the surface temperature would have stabilized 4°C. lower, and an increased heat gain by C + R of 12 Cal/M^2/hr. would have resulted. Changes in peripheral flow, which usually initiated and were always in accord with the general trend of temperature regulation, were always opposed to the effects of changes in muscular activity and sweat rate on the basis of C + R exchange.

Several other physiological changes had minor effects. Pulmonary ventilation increased slightly as the body temperature rose, and marked hyperventilation was seen during chills. A proportionate rise in evaporative cooling from the lungs resulted, but this was never large or sustained. Heat exchange by pulmonary convection was always negligible. Muscular movement during chills increased wind velocity and promoted heat exchange by convection. This increase could not be measured accurately, but, by calculation from the data of Hardy, Milhorat, and Du Bois (15), it would have little overall significance. Pilar erection, seen regularly with chills, was assumed to have no important effect.

B. <u>The Patterns of Regulation</u>

These experiments show that a definite sequence of physiological reactions occur in the production and lysis of fever. In general, these are directed first, toward reducing the loss of body heat and second, toward increasing internal thermogenesis. More specifically, the earliest change is a restriction of peripheral blood flow, the next a decrease in sweat rate, and the last an increase in muscular activity in the form of a shaking chill. Two factors influence the pattern of these reactions—the nature of the environment and the strength of the pyrogenic stimulus. In a cool environment peripheral blood flow and sweating are restricted. When a pyrogenic stimulus is felt, no further reduction in these controls is possible if the environment is sufficiently cool, hence heat loss cannot be reduced, and heat production must be increased by a chill. The rapidity of the febrile rise and the height reached are proportional to the severity and duration of muscular activity. In warmer environments, peripheral flow and sweating are normally considerably higher and can, therefore, be ef-

fectively reduced. When heat loss is diminished a rise of body temperature begins. Unless the environment is very hot, however, only a small sparing of heat loss can be made, and a gradual rise in body temperature results. If a strong pyrogenic stimulus demands a sharp rise, heat production is increased by a chill in addition, even in very hot surroundings.

The lysis of fever may be a passive or active process. If a chill has occurred, the skin temperature may be so high at the beginning of defervescence that the increased loss of heat by convection and radiation plus that of evaporative cooling from insensible water loss, exceeds the rate of heat production, and the body cools. More commonly, however, defervescence is a process in which heat loss is actively increased, first, by a rise in peripheral blood flow, and second, by sweat secretion. Active cooling must be induced if no chill has taken place, if the environmental temperature is above the skin temperature or if rapid cooling is required.

Changes in peripheral blood flow and sweat rate were closely associated and nearly synchronous except in a few instances where the rise and fall of heat content proceeded very slowly and changes in peripheral flow were noted first. While it should be possible theoretically to reach a febrile state by restriction of peripheral flow alone, such a case was not observed.

No tendency was noted for fevers to be more severe in hot surroundings, giving further evidence of the adaptation of the pattern of temperature control to the thermal properties of the environment. It seems probable that fever caused by natural infections and many other pyrogenic agents follow the same sequence of reactions as observed in these studies although this has no experimental confirmation. Barr, Cecil, and Du Bois (13, 14) found no significant difference in regulation during fevers due to typhoid vaccine and to malaria. The occurrence of a latent period between the time of typhoid injection and the first evidence of any disturbance in thermal regulation is consonant with the thesis that the typhoid organism must undergo alteration within the body or that a "pyrexin" (Menkin (15)) must be formed before the temperature regulating center is stimulated.

C. Other Considerations

The skin and rectal temperatures proved imperfect indices of heat content at average body temperature, as noted previously by Barr and Du Bois (14). The rectal temperatures lagged behind changes in heat content and, following chills, the maximum rectal temperature might not be attained until 45 minutes after the peak heat content was reached. Changes in skin temperature were more sensitive to changes in heat content but the absolute value of skin temperature was a poor index of average body temperatures.

In Table II, the rates of evaporative water loss during a cycle of fever are compared with water loss at rest in the same environment. The data indicate that if evaporation is not impeded, excessive sweating contributes little to the dehydration sometimes seen in fever.

TABLE II

EVAPORATIVE WATER LOSS DURING CONTROL AND FEVER EXPERIMENTS

Subject	Environmental Temperature °C	Evaporative Water Loss in Control Run gm/hr	Increase in Evaporative Water Loss in Fever gm/hr.	
			Run 1	Run 2
I	29	39	30	32
II	29	28		
II	29*	32	39	
III	29	50	28	30
IV	32	65	6	30
V	32	109	-1	-21
VI	38	223	-2	6
VII	38	204	-3	
VIII	38	242	-5	15
IX	43	319	2	11
X	43	341	5	

*Vaccine injected but no febrile reaction.

In fevers seen in clinical practice, the patient makes use of other controls of thermal regulation in addition to the autonomic mechanisms which have been described. These are voluntary and include regulation of his personal environment by the putting on and off of clothing, alterations in posture, and possibly changes in muscular activity. The addition of clothing is common during the febrile rise and creates a warmer environment. This may allow fever to occur without a chill by the pattern of regulation described for warm environments. In this connection it was noted in our studies that severe discomfort was experienced by the subjects only during chills. The patient during the rise frequently assumes a hunched position which reduces heat loss by convection, radiation, and evaporation. Restlessness may increase heat production very slightly.

In the lyses of fever, if clothing is removed, the cooler environment reduces the requirement for active cooling. Occasionally, a spread-out position is assumed which increases heat losses by convection, radiation, and evaporation. The patient in defervescence characteristically is quiet.

If enough clothing is not removed during lysis, interference with evaporation leads to excessive sweating. When a normal temperature is reached, residual moisture in the clothing continues to evaporate and cools the patient excessively. This may account for the occasional chills seen after rapid defervescence.

IV. SUMMARY AND CONCLUSIONS

Fever in man was studied calorimetrically to determine, first, the heat flows which cause changes in body temperature and, second, the physiological regulations which directly control these flows. Seventeen reactions induced by typhoid vaccine were observed in environments ranging in ambient temperature from 27° to 43°C.

Changes in body temperature are due almost entirely to autonomic regulation of peripheral blood flow, sweat secretion, and muscular activity. Peripheral blood flow, by altering the skin temperature, is a control of heat exchange by convection and radiation; sweating is a control of evaporative cooling; and muscular activity, in the form of chills, controls metabolic heat production. Sweating and muscular activity secondarily cause changes in convection and radiation. These changes are opposed to the primary thermal effects of sweat secretion and chills, but are smaller in magnitude.

The pattern of temperature regulation in fever is governed by the thermal nature of the environment and the strength of the pyrogenic stimulus. Whenever possible, temperature changes are brought about by altering the rate of heat loss from the body rather than by changing the rate of heat production.

To raise the body temperature, heat production can be increased, heat loss restricted, or both changes can be induced.

Peripheral blood flow and sweating must be restricted in order to maintain a normal body temperature in a cool environment. Since heat loss cannot be reduced further, a febrile rise can be accomplished only by increasing heat production, i.e., muscular activity, and the degree of fever will be proportional to the severity of the chill. When the environment is warm (above 30°C.) fever can be produced by decreasing heat loss, i.e., restriction of peripheral blood flow and sweat secretion. Unless the environment is very hot, however, only gradual temperature rises can be effected. If the pyrogenic stimulus demands a sharp rise in temperature, a chill is superimposed on restricted heat loss even in very hot environments.

The lysis of fever may be a passive or an active process. Passive cooling occurs when there is no increase in peripheral blood flow or sweat secretion. The skin temperature is elevated at the height of fever and the greater loss of heat by convection and radiation exceeds heat production. Passive cooling can occur only in a cool environment after fever induced by a chill, or after a fall in environmental temperature. When peripheral blood flow and/or sweating increases, as is usually the case, cooling is active. Active cooling is necessary in hot environments, or in cooler surroundings to produce rapid defervescence.

V. RECOMMENDATIONS

None.

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SOME PRELIMINARY OBSERVATIONS ON THE EFFECTS OF ULTRAVIOLET LIGHT, ALPHA RAYS AND X RAYS ON 2,3,5-TRIPHENYLTETRAZOLIUM CHLORIDE SOLUTIONS*

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1 December 1948

ABSTRACT

SOME PRELIMINARY OBSERVATIONS ON THE EFFECTS OF ULTRAVIOLET LIGHT, ALPHA RAYS AND X RAYS ON 2,3,5-TRIPHENYLTETRAZOLIUM CHLORIDE SOLUTIONS*

OBJECT

Noticing that ultraviolet light produced color changes in 2,3,5-triphenyltetrazolium chloride solutions, it was believed important to explore this phenomenon in relation to different types of radiant energy. The experiments here reported are to be regarded as exploratory in nature.

RESULTS AND CONCLUSIONS

Ultraviolet light (3650 Å to 2536 Å) reduces 2,3,5-triphenyltetrazolium chloride in solution to its red formazan. The amount of reduction depends upon the intensity of the light source and/or the time of exposure. The rate of formation of the red formazan increases with an increase in concentration of the salt solution. The reduction is influenced by pH and temperature.

Alpha radiation and x radiation also reduce 2,3,5-triphenyltetrazolium chloride to its red formazan.

It is believed that this study is an experimental contribution to the theory of Weiss on radiochemistry of aqueous solutions.

RECOMMENDATIONS

The importance of the application of this phenomenon in ultraviolet dosimetry, in medical therapy and in climatological problems is obvious.

More extensive studies on types and amounts of radiation, especially as to exact ionic yield should be undertaken. The radiochemical behavior of other tetrazolium compounds such as "Neotetrazolium" and 2,3-diphenyl-5-methyltetrazolium should be investigated.

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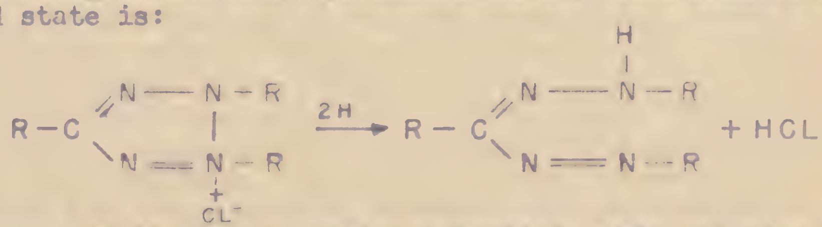
SOME PRELIMINARY OBSERVATIONS ON THE EFFECTS OF ULTRAVIOLET LIGHT, ALPHA RAYS AND X RAYS ON 2,3,5-TRIPHENYLTETRAZOLIUM CHLORIDE SOLUTIONS

I. INTRODUCTION

2,3,5-Triphenyltetrazolium chloride (TTC) was first synthesized in 1894 by Pechmann and Runge (1). Kuhn and coworkers (2,3) took up the study in 1941 and reported, among other properties, its oxidation reduction potential, namely, -0.08 volt in the pH range 5.7 to 6.[illegible]. Attention to this substance in America was brought about by the work of Dutcher (4) who reviewed the work of Lakon (5) on topographical staining and analysis of grain seed. Porter, Durrell and Romm (6), also reported on its use as an indicator of seed viability. Cottrell (7) confirmed Lakon's work in 1947 as did also Shuel (8). Mattson, Jensen and Dutcher (9) used it as a test reagent for checking vitality of tissues other than seeds. Waugh (10) then used this salt as a stain for living stem tissue and leaves. Pratt, Dufrenoy and Pickering proposed it as a reagent in cellular physiology (11). Straus, Cheronis and Straus (12) were the first to explore its uses in animal tissue, both normal and malignant.

According to the above published works, the formula for TTC and its reduced state is:



Because of its low reduction potential, this colorless water soluble tetrazol is easily reduced by chemical as well as phytochemical means to its red, water-insoluble, nondiffusible formazan.

Noticing that ultraviolet light influenced solutions of this salt, it was believed important to explore this phenomenon further, not only studying light, but also other radiations. The experiments to be reported are to be regarded as purely exploratory in nature.

II. EXPERIMENTAL

A. Methods and Procedures

1. Photochemical Investigations. The first investigations into the effect of ultraviolet light on TTC were started with fluorescence equipment assembled for work with fluorescent vital stains. It consisted of an ordinary microscope, ultraviolet light source and eye protective filter. Illumination sources were a Leitz carbon arc lamp with a Beckman B-2 and B-4 filter combination or the Spencer 353 fluorescence lamp. The eye protective filter was a Wratten [illegible]-3, located in the eyepiece. To obtain better efficiency, the standard microscope mirror was replaced by an aluminized front surface mirror.

Doing vital staining work with Allium Cepa epidermis and modern fluorochromes, TTC was also included in the investigations. It was noted that a section of living onion epidermis subjected to TTC solution became pink. This was expected according to the published work. However, while observing this preparation in the fluorescence equipment, it developed in addition to the normal pink color a bright red spot. To be certain that this was not due to a possible stimulation of cellular activity, a clear drop of TTC solution was placed on a glass slide and observed under identical conditions. Here also, the red precipitate was formed. With the formation of the red spot, fluorescence appeared in the fluid and increased in intensity to saturation during the observation period.

In systematic investigations, the nature of the red precipitate was determined, also the effective reduction wave length, the effect of temperature, pH, concentration, intensity of light and exposure time. For these purposes, aqueous TTC solutions and TTC gelatin emulsions of known concentration were prepared. The chemical was dissolved in distilled water with a pH normally adjusted to 6 with phosphate buffer; for special investigations, buffered solutions with pH ranges from 1.3 to 11 were prepared. The TTC emulsions contained in general 10% gelatin and 1% TTC.*

A series of varying exposures under standard irradiation conditions was made. Samples were exposed in the appropriate cuvettes and also as emulsions on 4 x 5 glass plates. Density measurements of the cuvettes were at first made in a Coleman junior spectrophotometer and later the results were confirmed on a Beckman quartz spectrophotometer. The density measurements of the plates were made with a Weston densitometer and later with the self-recording General Electric spectrophotometer. This instrument was also used to identify the photochemically produced red substance with chemically reduced TTC (zinc-reduction) by comparing the absorption spectra. Irradiation sources were the sun, the Hanovia U-burner and the Hanovia Alpine lamp. The General Electric H-4 lamp was also satisfactory. For studying the effective wave lengths, the above sources were filtered by Corning or Wratten filters. Filters with sharp cutoffs or monochromats were especially useful. The results obtained were later verified by exposure of gelatin emulsion plates in the large Littrow quartz spectrograph using, for slit illumination, either National Super-Tan carbons or the Hanovia Alpine mercury lamp.

2. Radiochemical Investigations. This work was extended from the photochemical into the radiochemical regions. Both alpha rays and x rays were investigated.

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* TTC from 2 sources was used: (1) The Arapahoe Chemical Co., Inc., Boulder, Colorado; and (2) The Pannone Chemical Company, Farmington, Connecticut.

For the alpha ray work, three polonium preparations were available.* (The polonium was deposited on nickel foil 5 x 5 sq. mm. in size.) Their strength as of August 23, 1948 was: Preparation #1 - 2 millicuries; Preparation #2 - 0.1 millicurie; Preparation #3 - 0.0004 millicurie.

The same solutions and emulsions as used in the photochemical work were also taken in this study. The alpha ray bombardment was made in such a way as to capture the maximum energy of the alpha particles in the preparation.

Details are shown in figure 1.

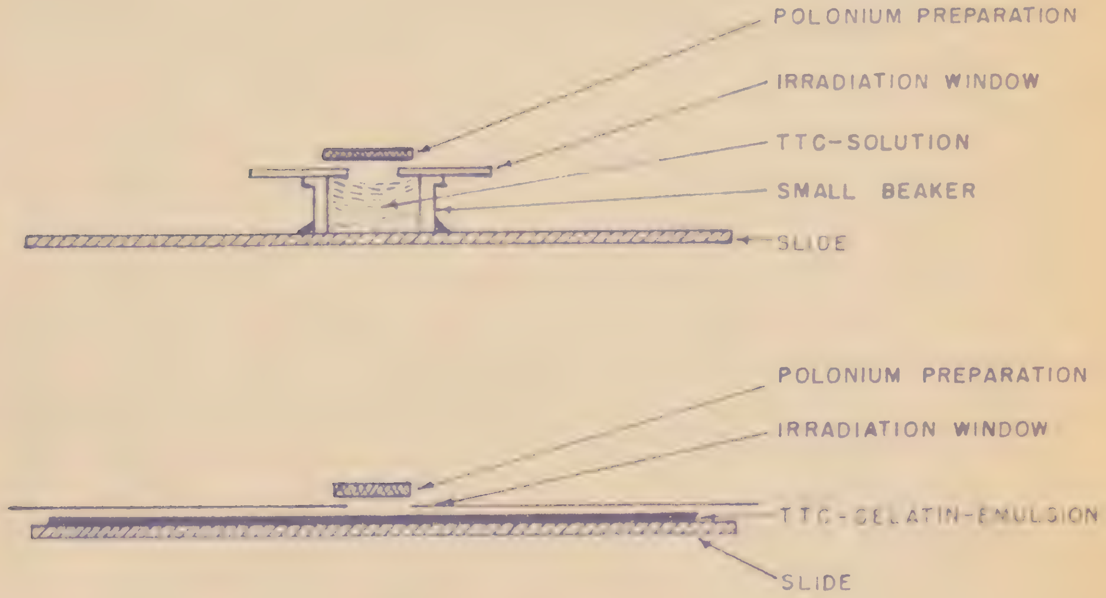

FIG. 1 DIAGRAM OF PREPARATION

The density of the alpha particle produced formazan in the plates was measured with the Weston densitometer.

The x ray exposures were carried out with aqueous TTC solutions and TTC emulsions that were sealed in small vials of 3 cc. each. These samples were exposed at a rate of 250 r/min/air and up to 130 minutes total irradiation time. The irradiation was done with 550 KV x rays through a composite filter equivalent to 9 mm. of copper.

* Obtained from Canadian Radium & Uranium Corporation, 630 Fifth Ave., New York 20, N. Y.

B. *Results*

The following results were observed:

1. By irradiating aqueous solutions of the clear, water-soluble 2,3,5-triphenyltetrazolium chloride with ultraviolet light, this chemical was reduced to its red water-insoluble formazan.

2. The reduction depends on the radiation wave lengths. Wave lengths longer than 3650 Å do not reduce, whereas wave lengths between 3650 Å and 2536 Å reduce effectively. The 2536 Å region was the lowest at our disposal.

3. The amount of formed precipitate is determined by the intensity of the light source, and/or the time of exposure. Figure 2 shows that graduated exposures give an increasing density.

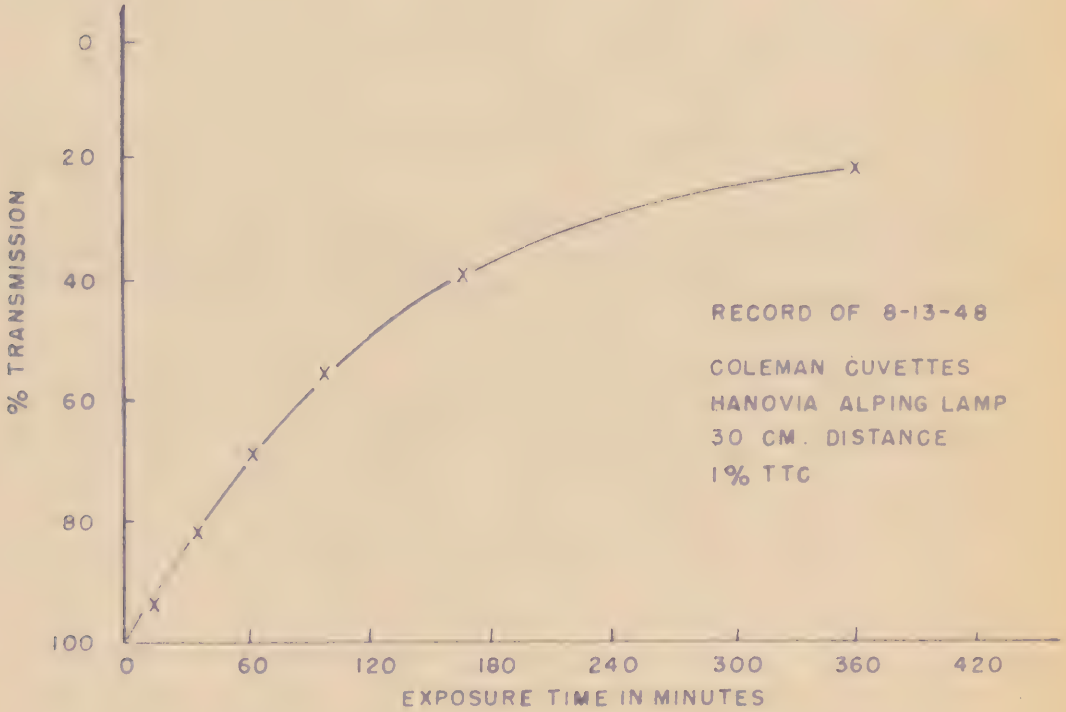

FIG. 2 REDUCTION OF TTC SOLUTION BY ULTRAVIOLET LIGHT

4. The rate of formation of the red precipitate increases with increase of concentration. The radiation effects are more pronounced in the early time intervals as shown in figure 3.

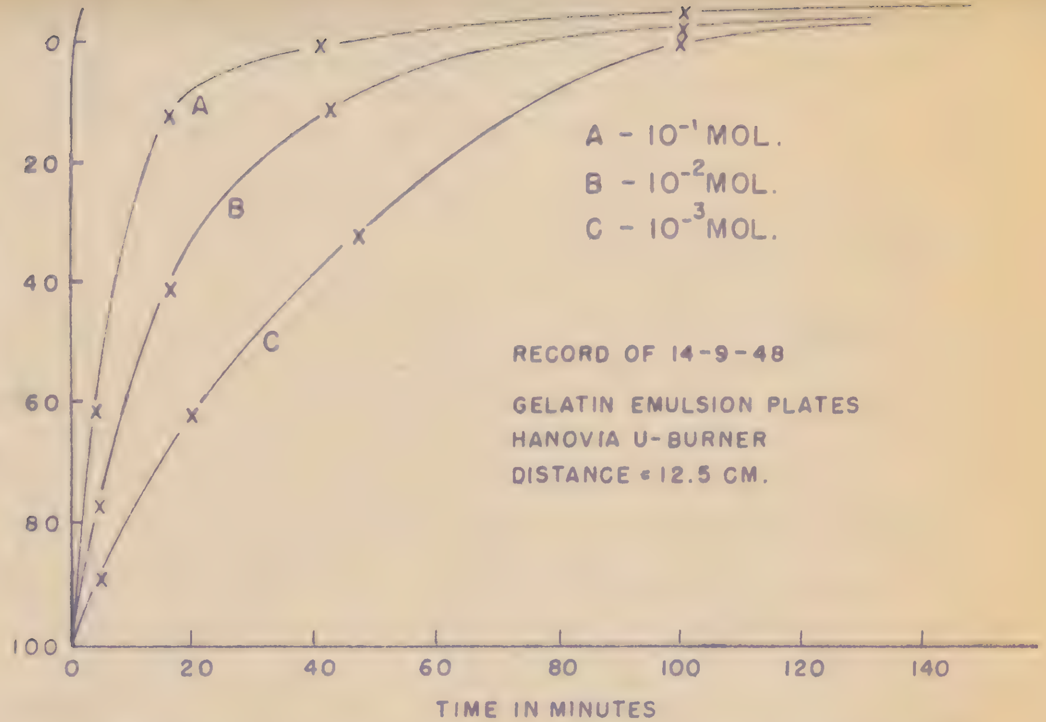

FIG. 3 REDUCTION OF TTC SOLUTION BY ULTRAVIOLET LIGHT: EFFECT OF CONCENTRATION

5. The pH influence, noticed early by Jerchel and Möhle (3), also exists in irradiation reduction. The reduction rate is the same in pH range 5.5 to 6.6 where also the reduction potential is constant. See figure 4.

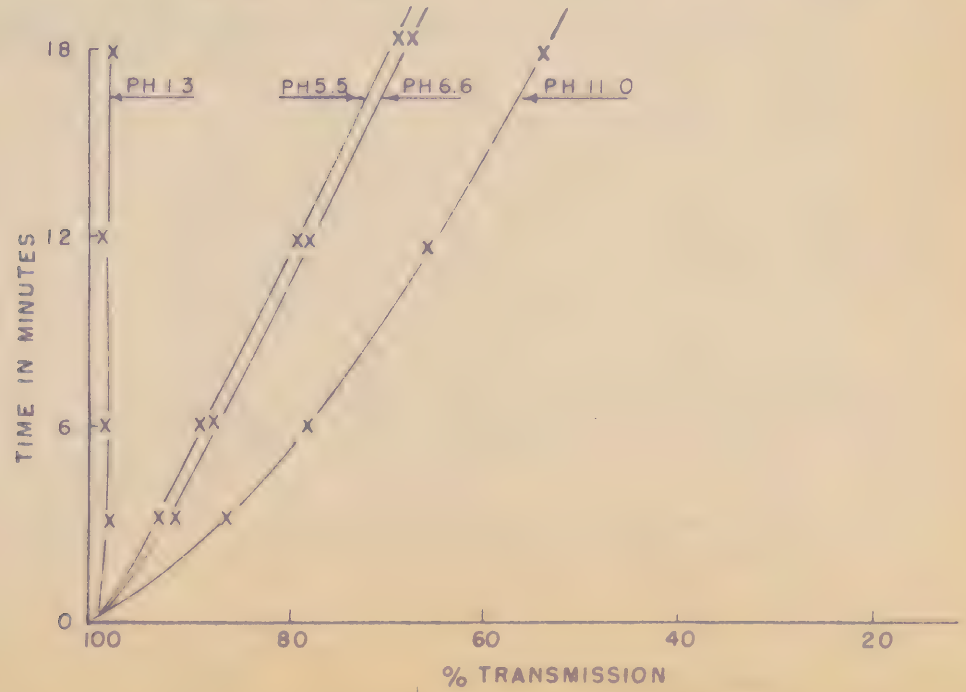

FIG. 4 REDUCTION OF TTC SOLUTION BY ULTRAVIOLET LIGHT: EFFECT OF PH.

6. Higher temperatures accelerate the reduction process. For example, with a temperature difference of 100°C (0° - 100°) and at a two-minute irradiation under the chosen standard conditions, there is 15% difference in transmission. See figure 5.

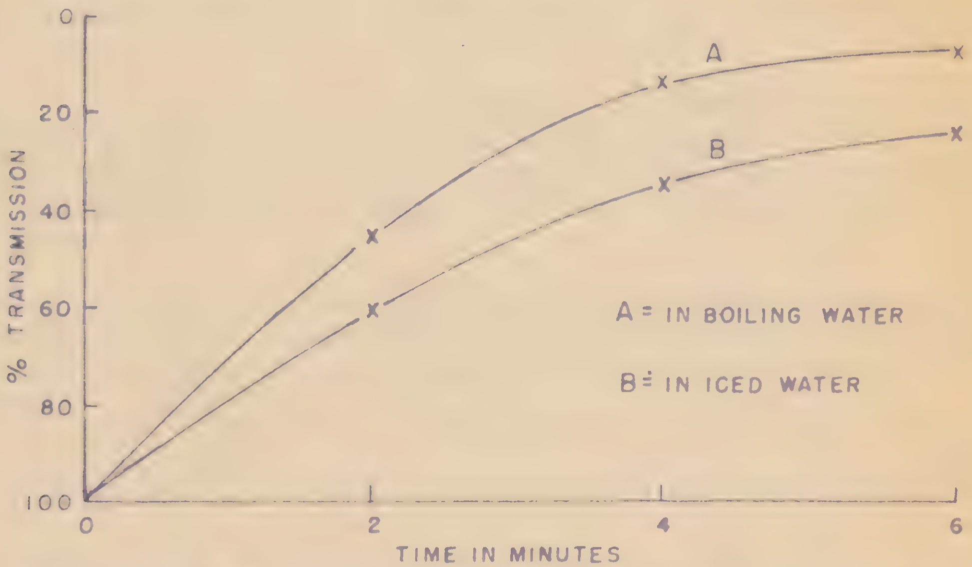

FIG. 5. REDUCTION OF TTC SOLUTION BY ULTRAVIOLET LIGHT: EFFECT OF TEMPERATURE

7. Alpha rays from polonium samples behave in a similar manner as ultraviolet light. Also here, tetrazolium in aqueous solution or in a gelatin emulsion is reduced to red formazan. The millicurie strength, the exposure time and the concentration of the tetrazolium are significant. See figure 6.

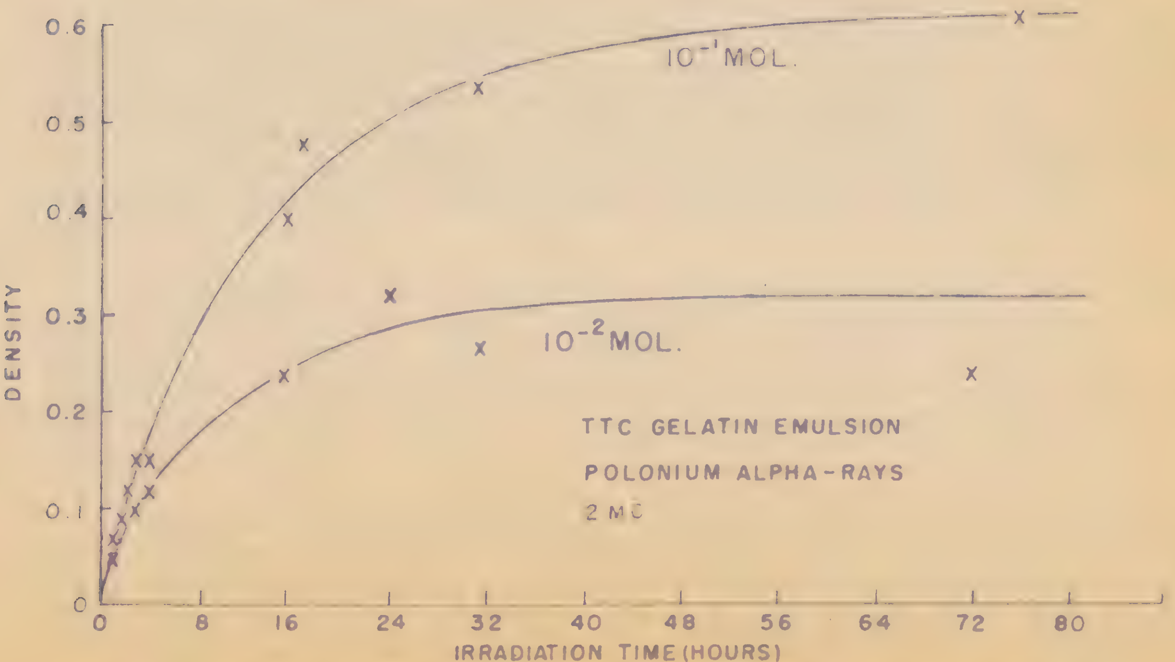

FIG. 6. REDUCTION OF TTC SOLUTION BY ALPHA-RAYS FROM POLONIUM.

C. X rays also reduce TTC solutions. The amounts necessary are relatively high but essentially of the same order of magnitude as polonium alpha rays. The earliest visual effect was produced by 32,000 r/air.

III. DISCUSSION

The observed results raise the question as to the mechanism of these effects.

TTC is reduced, according to chemical knowledge, by taking up hydrogen atoms. Consequently, hydrogen atoms must be produced by irradiation. This could happen by an indirect effect of the radiation on the solvent (water in this case), or by direct effect on the solute (TTC), raising it to an activated state.

That ionizing radiation converts water molecules into free hydrogen atoms and hydroxyl radicals has been postulated by the theory of Weiss (13). According to Weiss, in the radiation of water, the following electron transfers occur:

$$H^{+} \quad OH^{-} + \quad \text{Radiation} \longrightarrow H + OH$$

$$H_2O \;....\; H_2O + \text{Radiation} \longrightarrow H_2O^{-} \;....\; H_2O^{+}$$

followed by:

$$H_2O^{-} \longrightarrow H + OH^{-}$$

$$H_2O^{+} \longrightarrow H^{+} + OH$$

All of these processes are energetically possible and have been confirmed independently by photochemical evidence.

The produced hydrogen atoms and hydroxyl radicals are chemically very reactive (14,15) and if there are in the solution appropriate acceptors, they will react with these radiation products. Since biological systems are primarily solutions, the radiobiological implications of the above statements become apparent. So, for instance, dissolved oxygen in water is such an acceptor and irradiation leads to the production of H_2O_2. Such an acceptor, favored by its low reduction potential, must be also tetrazolium chloride.

The production of the effect by ultraviolet light with wave lengths up to 3650 Å requires further investigation. It may be explained by a direct effect on TTC, so that similar to photosynthetic processes (Rabinowitch (16)) excited intermediate states are formed. The observed fluorescence, which increases with the irradiation time, favors this hypothesis.

There may also be an explanation on the basis of the data given by Lea. According to Lea (17), 5 electron volts (eV.) are required to convert water into H and OH radicals. The wave length 2536 Å has a quantum energy of 4.89 eV, an amount close to the number given by Lea, but very dissimilar to the known water dissociation energy of about 13 eV (18). Further inves-

tigations, especially into the ionic yield, will give additional data and also new insight as to the parallelism between photochemical and radiochemical effects.

In a certain degree, these results and this discussion of photochemical and radiochemical behavior of TTC solutions are a further continuation of the theory of Weiss on the effects of radiation on water and aqueous solutions as it has been discussed and used by Lea (17) and at the conference in London on certain aspects of the action of radiation on living cells (19), and by Barron (20) at the forty-ninth meeting of the American Roentgen Ray Society, 1948.

IV. CONCLUSIONS

Previous investigations have shown that TTC solution can be reduced chemically. These experiments show that this substance can also be reduced by photochemical and radiochemical means.

Factors influencing this reduction, such as tetrazolium concentration, intensity of radiation, time of exposure, pH and temperature, were investigated. It is believed that this study is an experimental contribution to the theory of Weiss on the radiochemistry of aqueous solutions.

V. RECOMMENDATIONS

The importance of the application of this phenomenon is ultraviolet dosimetry, in medical therapeutics and in climatological problems is obvious. For instance, one can easily show in a pilot experiment how the ultraviolet intensity of the sun varies during the day. For this purpose a series of small vials containing 2-3 cc. of gelatin tetrazolium emulsion was exposed for two minutes on the hour every hour to the sun. The result is plotted in figure 7.

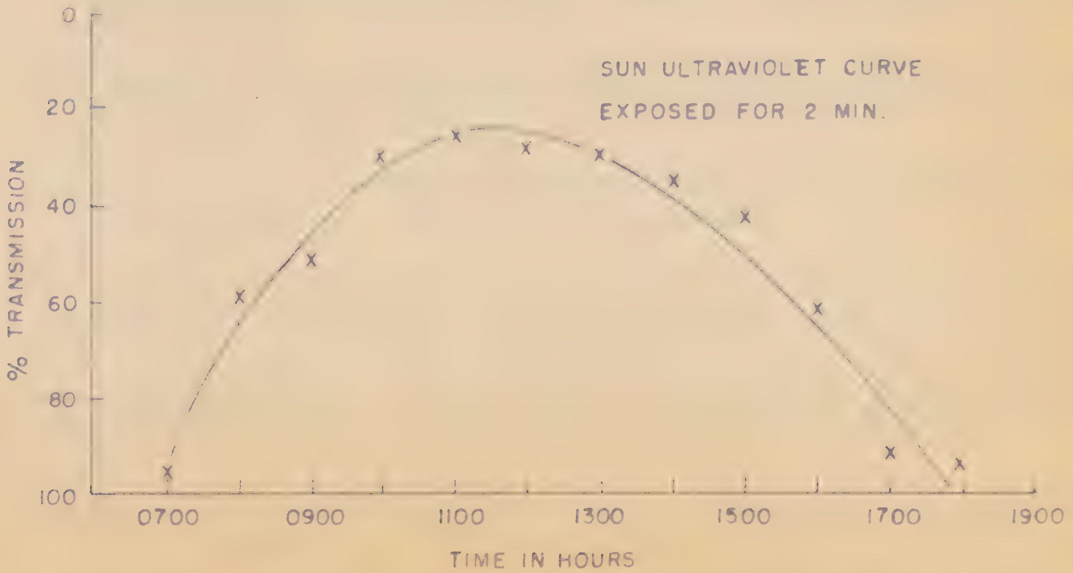

FIG. 7. REDUCTION OF TTC SOLUTION BY THE SUN.

Following this exploratory work, more extensive studies should be undertaken as to different types of radiation, the amounts of each necessary to reduce tetrazolium, and the exact ionic yield.

Other substituted tetrazolium salts such as Neotetrazolium (21) and 2,3 diphenyl-5-methyl TTC should be studied as to their radiochemical behavior.

VI. ACKNOWLEDGMENTS

We wish to express our gratitude to Dr. Kenneth E. Corrigan of Harper Hospital, Detroit, Michigan, who carried out the x-irradiation for us. Also to Dr. Hans F. Jensen of this laboratory for advice and encouragement.

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RADIATION EFFECTS ON 2, 3, 5-TRIPHENYLTETRAZOLIUM CHLORIDE SOLUTIONS

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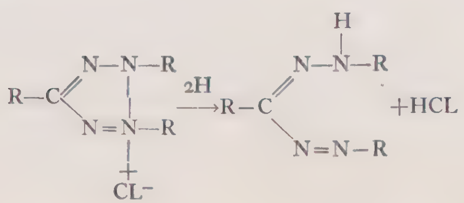
I. INTRODUCTION

2, 3, 5 - Triphenyltetrazolium chloride (TTC) was first synthesized in 1894 by von Pechmann and Runge.[11] Kuhn and coworkers[6,7] took up the study in 1941 and reported, among other properties, its oxidation reduction potential, namely, −0.08 volt in the pH range 5.7 to 6.8. Attention to this substance in America was brought about by the work of Dutcher[4] who reviewed the work of Lakon[8] on topographical staining and analysis of grain seed. Porter, Durrell and Romm[12] also reported on its use as an indicator of seed viability. Cottrell[3] confirmed Lakon's work in 1947, as did also Shuel.[15] Mattson, Jensen and Dutcher[10] used it as a test reagent for checking vitality of tissues other than seeds. Waugh[19] then used this salt as a stain for living stem tissue and leaves. Pratt, Dufrenoy and Pickering[13] proposed it as a reagent in cellular physiology. Straus, Cheronis and Straus[18] were the first to explore its uses in animal tissue, both normal and malignant.

According to the above published works, the formula for TTC and its reduced state is:



Because of its low reduction potential, this colorless water soluble tetrazol is easily reduced by chemical as well as phytochemical means to its red, water-insoluble, nondiffusible formazan.

Noticing that ultraviolet light influenced solutions of this salt, it was believed important to explore this phenomenon further, not only studying light, but also other radiations.

II. EXPERIMENTAL

A. *Methods and Procedures.*

1. Photochemical Investigations. The first investigations into the effect of ultraviolet light on TTC were started with fluorescence equipment assembled for work with fluorescent vital stains. It consisted of an ordinary microscope, ultraviolet light source and eye protective filter. Illumination source was a Leitz carbon arc lamp with a Beckman B-2 and B-4 filter combination. The eye protective filter was a Wratten K-3 located in the eyepiece. To obtain better efficiency, the standard microscope mirror was replaced by an aluminized front surface mirror.

Doing vital staining work with *Allium cepa* epidermis and modern fluorochromes, TTC was also included in the investigations. It was noted that a section of living onion epidermis subjected to TTC solution became pink. This was expected according to the published work. However, while observing this preparation in the fluorescence equipment, it developed in addition to the normal pink color, a bright red spot. To be certain that this was not due to a possible stimulation of cellular activity, a clear drop of TTC solution was placed on a glass slide and observed under identical conditions. Here also, the red precipitate was formed. With the formation of the red spot, fluorescence appeared in the field and increased in intensity to saturation during the observation period.

In systematic investigations, the nature of the red precipitate was determined, also the effective reduction wavelength, the effect of temperature, pH, concentration, intensity of light and exposure time. For

these purposes, aqueous TTC solutions and TTC gelatin emulsions of known concentration, as noted in graphs, were prepared. The chemical was dissolved in distilled water with the pH normally adjusted to 6.0 with phosphate buffer; for special investigations, solutions with pH ranges from 1.3 to 11.0 were prepared. The TTC emulsions contained in general 10 per cent gelatin and 1 per cent TTC.*

A series of varying exposures under standard irradiation conditions was made. Samples were exposed in the appropriate cuvettes and also as emulsions on 4 by 5 inch glass plates. Density measurements of the cuvettes were made in a Beckman quartz spectrophotometer. The density measurements of the plates were made with a Weston densitometer and later with the self-recording General Electric spectrophotometer. This instrument was also used to identify the photochemically produced red substance with chemically reduced TTC (zinc-reduction) by comparing the absorption spectra. Irradiation sources were the sun, the Hanovia U-burner and the Hanovia Alpine lamp. For studying the effective wavelengths, the above sources were filtered by Corning or Wratten filters. Filters with sharp cutoffs or monochromats were especially useful. The results obtained were later verified by exposure of gelatin emulsion plates in the large Littrow quartz spectrograph using, for slit illumination, either National Super-Tan carbons or the Hanovia Alpine mercury lamp. The exposure times were variable up to six hours.

2. Radiochemical Investigations. This work was extended from the photochemical into the radiochemical regions. Both alpha rays and roentgen rays were investigated.

For the alpha-ray work, three polonium preparations were available.† The polonium was deposited on nickel foil 5 by 5 sq. mm. in size. Their strength as of August 23, 1948, was: Preparation No. 1—2 millicuries; Preparation No. 2—0.1 millicurie; Preparation No. 3—0.0004 millicurie.

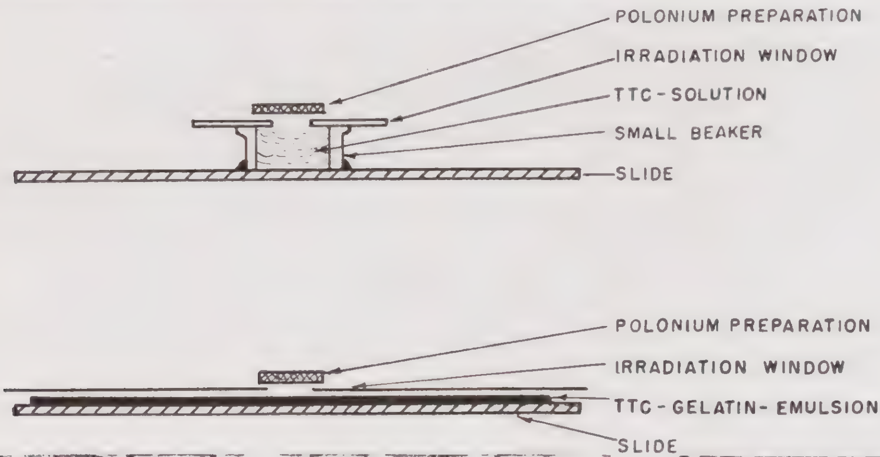


Fig. 1. Schematic diagram of alpha irradiation setup.

Solutions and emulsions of the same concentration as used in the photochemical work were also taken in this study. The alpha-ray bombardment was made in such a way as to capture the maximum energy of the alpha particles in the preparation. Details are shown in Figure 1.

The density of the alpha-particle-produced formazan in the plates was measured with the Weston densitometer.

The roentgen-ray exposures were carried out with aqueous TTC solutions and TTC emulsions that were sealed in small vials of

* TTC from 2 sources: was used: (1) The Arapahoe Chemical Co., Inc., Boulder, Colorado; and (2) The Pannone Chemical Company, Farmington, Connecticut.

† Obtained from Canadian Radium and Uranium Corporation, 630 Fifth Ave., New York 20, N. Y.

3 cc. each. These samples were exposed at a rate of 250 r per minute measured in air and up to 130 minutes total irradiation time. The irradiation was done with 550 kv. roentgen rays through a composite filter equivalent to 9 mm. of copper.

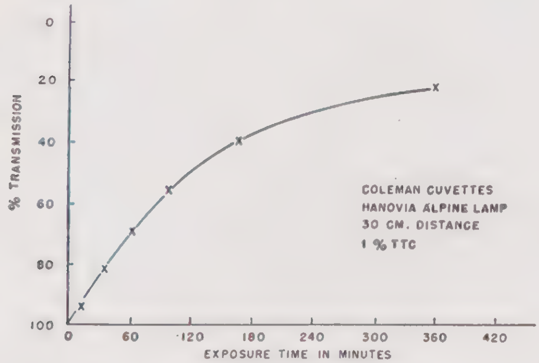


Fig. 2. Reduction of TTC solution by ultraviolet light.

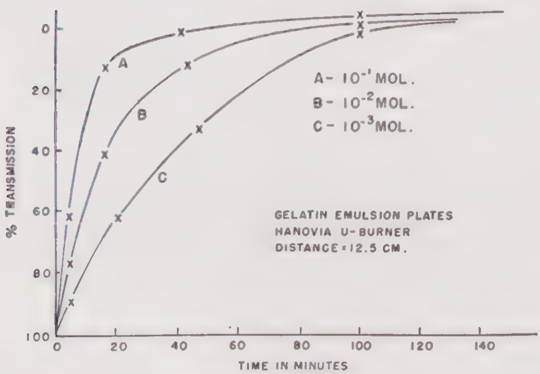


Fig. 3. Reduction of TTC solution by ultraviolet light: Effect of concentration.

B. *Results.*

The following results were observed:

1. By irradiating aqueous solutions of the clear, water-soluble 2,3,5-triphenyltetrazolium chloride with ultraviolet light, this chemical was reduced to its red water-insoluble formazan.

2. The reduction depends on the radiation wavelengths. Wavelengths longer than 3,650 Å do not reduce, whereas wavelengths between 3,650 Å and 2,536 Å reduce effectively. The 2,536 Å region was the lowest at our disposal.

3. The amount of formed precipitate is determined by the intensity of the light source, and/or the time of exposure. Figure 2 shows that graduated exposures give an increasing density.

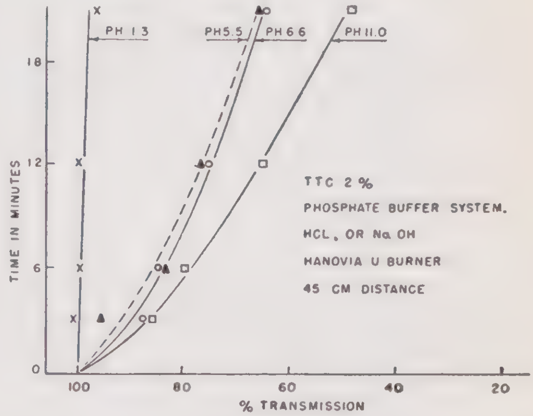


Fig. 4. Reduction of TTC solution by ultraviolet light: Effect of pH.

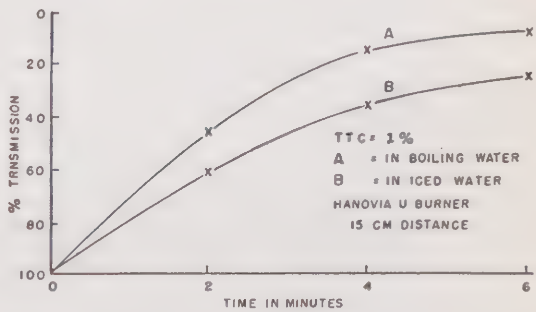


Fig. 5. Reduction of TTC solution by ultraviolet light: Effect of temperature.

4. The rate of formation of the red precipitate increases with increase of concentration. The radiation effects are more pronounced in the early time intervals as shown in Figure 3.

5. The pH influence, noticed early by Jerchel and Möhle,[6] also exists in irradiation reduction. The reduction rate is the same in pH range 5.5 to 6.6 where also the reduction potential is constant (see Fig. 4).

6. Higher temperatures accelerate the reduction process. For example, with a temperature difference of 100° C. (0°–100° C.) and at a two minute irradiation under the chosen standard conditions, there is 15 per cent difference in transmission (see Fig. 5).

7. Alpha rays from polonium sources behave in a manner similar to ultraviolet light. Also here, tetrazolium in aqueous solution or in a gelatin emulsion is reduced to red formazan. The millicurie strength, the exposure time and the concentration of the tetrazolium are significant (see Fig. 6).

8. Roentgen rays also reduce TTC solutions. The amounts necessary are relatively high. The earliest visual effect was produced by 32,000 r measured in air.

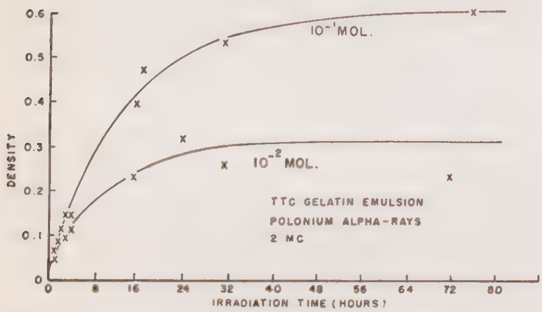


Fig. 6. Reduction of TTC solution by alpha rays from polonium.

III. DISCUSSION

The observed results raise the question as to the mechanism of these effects.

TTC is reduced, according to chemical knowledge, by taking up hydrogen atoms. Consequently, hydrogen atoms must be produced by irradiation.

That ionizing radiation converts water molecules into free hydrogen atoms and hydroxyl radicals has been postulated by the theory of Weiss.[20] According to Weiss, in the irradiation of water, the following electron transfers occur:

$$H^+ \; OH^- + \text{Radiation} \longrightarrow H + OH$$
$$H_2O \cdots H_2O + \text{Radiation} \longrightarrow H_2O^- \cdots H_2O^+$$

followed by:

$$H_2O^- \longrightarrow H + OH^-$$
$$H_2O^+ \longrightarrow H^+ + OH$$

All of these processes are energetically possible and have been confirmed independently by photochemical evidence.

The produced hydrogen atoms and hydroxyl radicals are chemically very reactive[5,21] and if there are in the solution appropriate acceptors, they will react with these radiation products. Since biological systems are primarily solutions, the radiobiological implications of the above statements become apparent. So, for instance, dissolved oxygen in water is such an acceptor and irradiation leads to the production of H_2O_2. Such an acceptor, favored by the low reduction potential, must be also tetrazolium chloride.

The production of the effect by ultraviolet light with wavelengths up to 3,650 Å requires further investigation. It may be explained by a direct effect on TTC, so that similar to photosynthetic processes (Rabinowitch[14]) excited intermediate states are formed (Rossi[14a]). The observed fluorescence, which increases with the irradiation time, favors this hypothesis.

There may also be an explanation on the basis of the data given by Lea. According to Lea,[9] 5 electron volts (ev.) are required to convert water into H and OH radicals. The wavelength 2,536 Å has a quantum energy of 4.89 ev. an amount close to the number given by Lea, but very dissimilar to the known water dissociation energy of about 13 ev.[16] Further investigations, especially into the ionic yield, will give additional data and also new insight as to the parallelism between photochemical and radiochemical effects.

To a certain degree, these results and this discussion of the photochemical and radiochemical behavior of TTC solutions are a further contribution to the theory of Weiss on the effects of radiation on water and aqueous solutions as it has been discussed and used by Lea[9] and at the conference in London on "Certain Aspects of the Action of Radiation on Living Cells,"[17] and by Barron[2] at the Forty-Ninth Annual Meeting of the American Roentgen Ray Society, 1948.

IV. SUMMARY

Previous investigations have shown that TTC solution can be reduced chemically.

These experiments show that this substance can also be reduced by photochemical and radiochemical means.

Factors influencing this reduction, such as tetrazolium concentration, intensity of radiation, time of exposure, pH and temperature, were investigated. It is believed that this study is an experimental contribution to the theory of Weiss on the radiochemistry of aqueous solutions.

Following this exploratory work more extensive studies should be undertaken as to different types of radiation, amounts of each necessary to reduce tetrazolium, and especially as to exact ionic yield.

Other substituted tetrazolium salts such as neotetrazolium[1] and 2,3 diphenyl-5 methyl-tetrazolium should be studied as to their radiochemical behavior.

We wish to express our gratitude to Kenneth E. Corrigan, Ph.D. of Harper Hospital, Detroit, Michigan, who carried out the roentgen irradiation for u also, to Dr. Hans F. Jensen of this laboratory for advice and encouragement.

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MEDICAL DEPARTMENT PROBLEMS IN COLD WEATHER OPERATIONS

BY

FREDERICK J. KNOBLAUCH
Lt. Col. M.C., U. S. Army

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MEDICAL DEPARTMENT PROBLEMS IN COLD WEATHER OPERATIONS*

By LIEUTENANT COLONEL FREDERICK J. KNOBLAUCH, M.C., *Commanding Officer*
Medical Department Field Research Laboratory

THE effort to protect the military man againt his environment is a new and rapidly developing science. The global nature of World War II focused belated attention to the fact that little had been done in the prewar years to prepare the soldier and his equipment to withstand the rigors of the many varied climatic conditions to be encountered in world-wide theaters of operation. The pressure of war demanded the production of machines of war in huge quantities but allowed little time for the study of the additional stresses and strains placed upon the individual in the operation of these machines.

The battlefield was usually the proving ground and many lessons were learned the hard way. All services realized their difficulties early and tremendous efforts were made to correct shortcomings in design of equipment to lessen the hazards to the individual and to improve his efficiency and comfort. The great lesson learned by all has been the vital necessity for peacetime research and development.

Technological advances in machines of war usually outstrip information and fundamental data on the requirements of man to operate them. It is an important step in the right direction that many branches of the service have established laboratories and testing agencies to study the effects of climatic extremes upon the military man and his equipment. Many of the questions can not be answered in the laboratory, therefore, extensive field testing is necessary.

Quite a bit of publicity has been given to the Arctic exercises of last winter and to this winter's exercises in New York and Alaska. During all of these exercises, Medical Department Personnel have been engaged in studying the effects of extremely low temperatures upon medical installations, responsibilities and supplies.

If it is borne in mind that even minor physical effort may become tremendously laborious in the Arctic and that the greater portion of man's total energy output is used up in the effort to survive in the extreme cold, the magnitude of the problem will be more fully realized.

The subject can not be adequately covered in a paper of this length, therefore, I shall attempt to outline briefly some of the major problems of the Medical Department in cold weather operations. The problem of early location and evacuation of casualties stands out as one of major importance to the Medical Department. It will be extremely difficult to locate casualties wearing uniform camouflage in areas where limited visibility is common. Some type of marker system must be devised to assist ground and air search. There is little doubt but that close ground-air liaison in casualty location will be of great importance.

* Presented at the 54th Annual Convention of the Association of Military Surgeons, Hotel Statler, Boston, Massachusetts, November 13-15, 1947.

The great value of prompt first aid and early evaculation to a place where definitive treatment can be administered is well known, however, its importance is amplified many times under Arctic conditions. Survival time without aid is markedly shortened, therefore, the Medical Department must meet the challenge by developing new and faster methods of casualty location and evacuation. Litter bearing is tremendously exhausting and is, therefore, impractical except for very short distance. It is a known fact that a man can pull much more than he can carry over snow and ice, therefore, some form of sled or snow boat will probably replace the litter. Over-snow vehicles such as the tracked ambulance, weasel, and snowmobile with heated cabs and trailers will probably bear the brunt of evacuation in forward areas. Consideration must also be given to the utilization of dog teams, small airplanes and helicopters. Air lift will probably be the method of choice from forward medical installations to airstrips and railheads in the rear.

In view of the low visibility, absence of landmarks and the ease of getting lost, serious consideration must be given to furnishing evacuation vehicles, medical units and installations with some means of communication. A vehicle may become hopelessly lost in a blizzard only a few hundred yards from its destination. Without some means of communication with other units or vehicles the chances of survival of the occupants until located by search parties would be slight.

The problems of sanitation in the Arctic also require considerable investigation. There are many difficulties to be overcome in the disposal of human and kitchen wastes at very low temperatures. The problem is not solved by assuming that methods commonly used in temperate climates can be easily modified to work satisfactorily in the Arctic. Many feet of snow and ice may overlie ground which is permanently frozen. The burial of wastes under such conditions requires the use of dynamite. Areas will become quickly contamined if waste material is scattered over ice. This is particularly true during the warmer season when some thawing occurs. Wherever possible it would appear that incineration is the method of choice in waste disposal. Other means will have to be devised for use away from base camp or bivouac.

Furnishing a supply of potable water is an engineer responsibility but is also of interest to the Medical Department. It is no easy job to maintain an adequate supply of water by melting ice and snow. Heated tanks are necessary for water storage. Transportation from storage points to users requires heated or insulated tank trailers or containers. It is time consuming for each individual to attempt to melt his own supply, however, immersion type heaters in G.I. cans will furnish a fair supply for small groups.

Strict personal hygiene will only be enforceable in base camp, however, it appears reasonable to assume that troops will not be away from a camp or bivouac for long periods.

All shelter must be heated and the wide use of gasoline as a heating fuel makes ever present the dangers of carbon monoxide and chronic lead poisoning.

The proper training of troops for duty in cold climates can not be overstressed. The Arctic is friendly only to those who know it. A great deal can be learned from native customs about survival at very low temperatures and all troops should be thoroughly indoctrinated with a knowledge of bushcraft and means of protecting themselves while in the field. The soldier must know his equipment and how to employ it to the best advantage to increase his chances of survival if injured or separated from other troops. He must know his Arctic clothing and its proper utilization to fit his military task. Clothing which is sufficient to keep a man warm while resting becomes too warm when he is working. Clothing must be loosened and properly ventilated to prevent destruction of its insulation value by perspiration. The soldier must realize that violation of this principle will get him into serious difficulties and may well cost him his life. He should be familiar with first aid measures and how to prevent frostbite and snowblindness as well as what to do if it should occur.

The problem of medical supplies for use

in the Arctic requires considerable study. Solutions will freeze during shipment and storage, and glass containers will be broken. New methods and materials for packaging will be necessary. The probability of supply by air requires that consideration be given to reduction of bulk and weight of all supplies and equipment.

The location of medical installations and units must be in keeping with new concepts on the tactical employment of troops in Arctic climates. Many agencies are engaged in studying all of these problems and good progress is being made.

It was not my intention to slight the many other important medical problems such as communicable diseases, nutrition, psychology, etc., however it is hoped that the range of those outlined will at least indicate the need for much additional information.

In closing, I would like to stress the importance of three approaches that are being utilized in the search for answers:

1. The use of trained observers in the field. An untrained observer is an unreliable reporter.
2. The use of trained technicians to perform field tests and collect data.
3. Laboratory testing and experimentation to correlate and substantiate the data obtained from the first two sources.

The coordinated efforts of these three methods of study will result in information with a sound scientific basis and will avoid the too frequent coloring matter of personal opinion.

EFFECTS OF THE COLD PRESSOR TEST ON GLOMERULAR FILTRATION AND EFFECTIVE RENAL PLASMA FLOW

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EFFECTS OF THE COLD PRESSOR TEST ON GLOMERULAR FILTRATION AND EFFECTIVE RENAL PLASMA FLOW

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THE cold pressor test is a well-known method of determining the ability of the vasomotor system to respond to reproducible stimuli.[1-4] Exposure of the hand or other body areas to ice water has been shown to cause pain, local vasoconstriction, and an elevation of arterial blood pressure.[5, 6] Recently attention has been drawn to the effects of a local cold stimulus on renal function. Diminished urinary volume, increased specific gravity, decreased urea clearance values, and reduced minute chloride output have been observed following moderately prolonged exposure to the stimulus of the cold pressor test in pregnant and nonpregnant women.[7] Equivocal observations of these phenomena have been reported on other subjects.[8] It is the purpose of this paper to report the effects of local peripheral cold on the specific renal functions of glomerular filtration and effective renal plasma flow.

METHODS

The subjects for these experiments were healthy white male volunteers between the ages of 18 and 37 years who on physical examination and urinalysis showed no evidence of renal disease. The men were asked to abstain from all solid food and liquids, with the exception of one glass of water at bedtime, after supper on the evening prior to the experiment.

On the morning of the experiment the subject assumed a reclining position. An indwelling soft rubber catheter (5.5 mm. in diameter) was installed in the bladder. Following the application of a blood pressure cuff to the left arm, intravenous infusions of isotonic saline were started in the veins of each forearm at a rate of 1 ml. per minute. The needle in the left arm was used for drawing blood samples, that in the right, for the administration of test substances. While these procedures were being carried out (a period of about one hour), the subject ingested 1 liter of water. Then a priming dose of 40 ml. of a 25 per cent mannitol solution* and 3 ml. of a 20 per cent sodium para-aminohippurate solution* was administered intravenously within a period of five minutes. This was followed immediately by a sustaining infusion consisting of a mixture of 600 ml. of isotonic saline, 100 ml. of a 25 per cent solution of mannitol, and 16 ml. of a 20 per cent solution of sodium para-aminohippurate at a rate of 4 ml. per minute. This rate was maintained throughout the experiment.

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*Obtained from Sharp & Dohme, Inc., Philadelphia, Pa.

Zero time was established at thirty minutes after the beginning of the priming dose. Six or seven consecutive clearance periods, of approximately fifteen minutes each, were carried out. After the first two or three of these periods, which served as controls, the subject's left foot was immersed to the level of the malleoli in stirred ice water at 1° C. and was kept there throughout one entire period. Following removal of the foot from the cold stimulus, clearances were measured for three or four more periods.

Approximately five minutes after the beginning of each clearance period, blood samples were drawn through a three-way stopcock attached to the needle in the left arm; care was taken to rinse out the system several times, using withdrawn and reinjected blood in order to wash out any residual saline. Time was noted, to the nearest tenth of a minute, at the beginning and end of the drawing of each sample and the average was taken as the blood sampling time. At the end of each period the bladder was washed with 20 ml. of saline and 20 ml. of air.

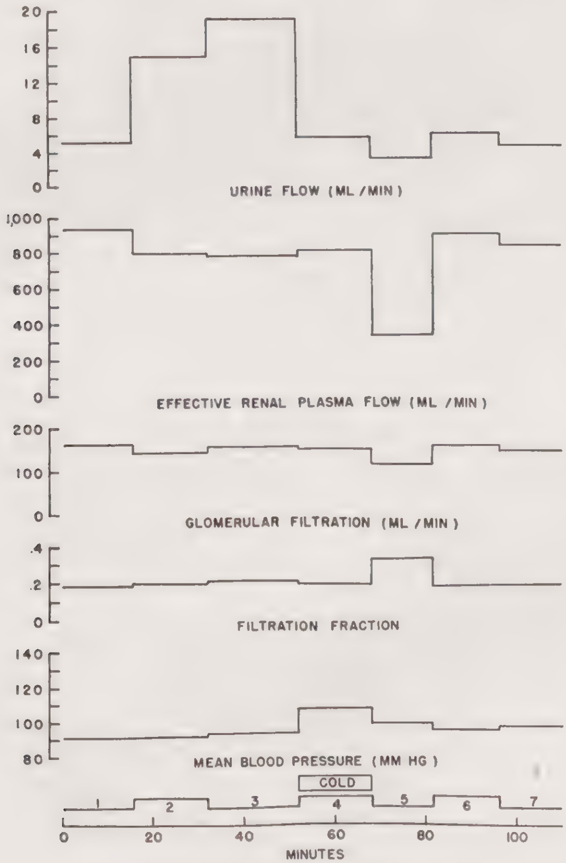

Fig. 1.—Representative experiment.

Auscultatory blood pressures were obtained at least twice during each of the control periods as well as within thirty seconds before and after immersion of the foot in the ice water. During the period of immersion and in the two

following periods determinations were made at approximately two-minute intervals. Thereafter, the frequency of the readings was similar to that during the control periods.

Analyses for mannitol and sodium para-aminohippurate were carried out on heparinized plasma and on diluted urine samples according to the methods of Corcoran and Page[9] and Smith and co-workers,[10] respectively. It has been suggested that the clearance of mannitol may be slightly lower than the true glomerular filtration rate.[11] This would not alter the interpretation of these experiments since the importance of these data lies in their relative rather than in their absolute values.

RESULTS

The results of these experiments are summarized in Table I. A representative experiment is shown in Fig. 1. As will be noted, in six out of seven subjects both glomerular filtration rate and effective renal plasma flow decreased either during the application of the cold stimulus or within approximately thirty minutes thereafter. In no subject did the effect persist longer. The average decreases in glomerular filtration rate and effective renal plasma flow, as compared with the controls, were 14 per cent and 21 per cent, respectively. The observed depression of urine flow confirms the finding of Odell and Aragon.[7]

In all subjects the blood pressure rose promptly after application of the cold stimulus and this rise was sustained throughout the period of immersion. Upon removal of the stimulus, the blood pressure gradually decreased, returning to control levels in fifteen to twenty minutes. Examination of these data reveals no correlation between the degree of blood pressure elevation and the observed changes in renal function.

DISCUSSION

The application of a peripheral cold stimulus is found to decrease urinary minute volume, glomerular filtration rate, and effective renal plasma flow.

The large reduction of urine flow as compared with the moderate depression of glomerular filtration rate is regarded as evidence of alteration in the tubular reabsorption of water. This antidiuretic response may be of the same nature as that demonstrated by Rydin and Verney in dogs subjected to emotional stress.[12]

The results obtained on Subject 3 (26 years of age) may be of interest. While the blood pressure rose in all experiments as a result of the stimulus, the rise was not associated with changes in glomerular filtration and renal plasma flow in this one subject. The initial diastolic blood pressure (128/90) together with the blood pressure response (164/116), during exposure to cold, would suggest, according to the criteria of Hines and Brown,[13] that this individual belongs to the prehypertensive group. However, as indicated above, these observations do not establish a correlation between the degree of blood pressure rise and the changes in renal function in response to the cold stimulus.

The mechanisms ultimately responsible for these findings remain to be identified and are being investigated.

Table I. Summary of Experiments

SUBJECT	DATE	CONDITION*	NUMBER OF PERIODS	AVERAGE DURATION (MIN.)	URINE FLOW (ML./MIN.)	MANNITOL PLASMA (MG./ML.)	MANNITOL CLEARANCE (ML./MIN.)	PAH PLASMA (MG./ML.)	PAH CLEARANCE (ML./MIN.)	FILTRATION FRACTION† (R)	AVERAGE MEAN B.P.‡ (MM. HG)	CHANGE§ OF C_M‖ (%)	CHANGE§ OF C_{PAH}¶ (%)	CHANGE§ OF AV. MEAN B.P. (%)
1	9/22/47	a	3	16.6	5.0	.635	164	.0360	711	.23	101			
	9/22/47	c	2	15.3	4.3	.671	150	.0325	542	.28	109	− 9	−24	+ 8
	9/22/47	p	2	14.9	4.8	.687	188	.0252	864	.22	103	+15	+22	+ 2
2	9/23/47	a	3	16.8	13.2	.725	152	.0280	822	.19	95			
	9/23/47	c	2	14.9	4.2	.801	133	.0292	562	.27	107	−12	−32	+13
	9/23/47	p	2	15.5	4.9	.821	147	.0251	843	.18	95	− 3	+ 3	0
3	9/24/47	a	2	15.9	13.1	.463	189	.0233	637	.30	116			
	9/24/47	c	3	14.5	8.7	.495	192	.0190	663	.29	133	+ 2	+ 4	+15
	9/24/47	p	2	15.1	9.4	.641	164	.0188	663	.25	120	−13	+ 4	+ 4
4	9/25/47	a	2	15.0	16.8	.513	182	.0165	696	.26	104			
	9/25/47	c	2	15.0	6.4	.519	132	.0141	508	.26	117	−28	−27	+13
	9/25/47	p	2	14.8	6.9	.546	154	.0178	645	.24	106	−15	− 7	+ 2
5	9/29/47	a	2	15.0	23.3	.744	153	.0193	926	.17	106			
	9/29/47	c	1	15.3	15.3	.770	118	.0180	711	.17	124	−23	−23	+17
	9/29/47	c	2	14.8	5.4	.936	117	.0192	737	.16	124	−23	−23	+17
	9/29/47	p	2	12.5	5.7	.972	128	.0170	862	.15	115	−16	− 7	+ 8
6	9/30/47	a	2	14.8	12.2	.502	179	.0150	891	.20	90			
	9/30/47	c	2	15.1	5.2	.590	154	.0175	566	.27	108	−14	−26	+20
	9/30/47	p	2	15.3	5.7	.680	191	.0160	790	.25	89	+ 7	+ 7	− 1
7	10/ 6/47	a	2	15.9	3.1	.791	116	.0244	627	.19	95			
	10/ 6/47	c	3	15.2	11.3	.810	102	.0256	486	.21	106	−12	−22	+12
	10/ 6/47	p	2	16.0	2.7	.971	114	.0266	655	.17	98	− 2	+ 5	+ 3
Average % of control		c										−14	−21	+14
Average % of control		p										− 4	+ 4	+ 3

*a, Control periods; c, periods of cold effect; p, recovery periods.

†Filtration fraction $= \dfrac{\text{Mannitol clearance}}{\text{PAH Clearance}}$

‡(Systolic + diastolic) ÷ 2 = Mean B.P. average of all readings.

§Change from control (a) average.

‖C_M, mannitol clearance.

¶C_{PAH}, Para-aminohippurate clearance change from control (a) average.

SUMMARY

Studies were made of the effects of the cold pressor test on renal function. Seven male volunteers who had no history of renal disease served as subjects. Glomerular filtration (as measured by mannitol clearance) and effective renal plasma flow (as measured by sodium para-aminohippurate clearance) were determined before, during, and after immersion of the foot in ice water at 1° C. for fifteen minutes.

In six out of seven subjects both glomerular filtration rate and effective renal plasma flow decreased either during the application of the cold stimulus or within approximately thirty minutes thereafter. In no subject did the effect persist longer. The average decreases in glomerular filtration rate and effective renal plasma flow, as compared with the control values, were 14 per cent and 21 per cent, respectively.

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QUARTERLY PROGRESS REPORTS
1 January - 31 December 1948

M D F R L

Q U A R T E R L Y   P R O G R E S S   R E P O R T

O N

R E S E A R C H   A N D   D E V E L O P M E N T

P R O J E C T S

January 1948 to April 1948

Proj. 1

[illegible]

6-64-12-02 Cold, Study of the Physiological Effects of. Approved [illegible] Sept. 1942.

6-64-12-0[illegible] High Temperatures, Study of Physiological Effects of. Approved [illegible] Sept. 1942.

6-64-12-05 Study of Body Measurements as They Affect Physiological Efficiency. Approved 31 May 194[illegible].

6-64-12-06 Study of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946.

6-64-12-07 Studies of Fatigue in Relation to Military Tasks. Approved 31 May 1946.

6-64-12-0[illegible] Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks. Approved 31 May 1946.

[illegible] Investigation of [illegible] Controls. Approved [illegible] February 194[illegible].

<u>Cold, Study of Physiological Effects of</u>. Approved 24 Sept. 1942 in order to study the physiology of subjects in cold environments.

Sub-Project M.D.F.R.L. 03-1: Studies of Physiological Problems under Field Conditions in Extreme Cold - Dr. G. W. Molnar, Physiologist, J. E. Blair, Capt. MC., C. R. Gottschalk, Capt. MC., L. E. Osgood, 1st Lt. MC., R. J. Zimmerman, 1st Lt. MC., W. H. Layton, 1st Lt. MC., and F. K. Smith, 1st Lt. MSC.

A field laboratory with some physiological equipment and facilities for several simple biochemical analyses has been established at Fort Churchill, Manitoba, Canada. Physiological and biochemical studies were made on seven subjects at Fort Knox, including observations during a two-week bivouac, to establish responses to stress in a temperate climate. The subjects were then sent to Fort Churchill, arriving 31 December 1947. After a period of indoctrination and conditioning, they moved into a bivouac 11 February 1948. For a 13-day period, the subjects lived under field conditions, eating C-2 rations and using General Issue Arctic tents and clothing. The subjects were subject to stress in the form of:

a. Extreme cold. The period of the bivouac included some of the most severe weather ever recorded at Churchill.

b. Limited water supply. The subjects obtained water by melting snow.

c. A routine of outdoor work including marching, snowshoeing and building of snow houses.

In spite of the severe stress, the morale of the subjects remained very high throughout the bivouac period, and all but one were able to complete the entire period.

During the bivouac period, daily blood samples were obtained on each subject and analyzed for cell volume, hemoglobin, sugar and specific gravity of plasma. Plasma samples were sent to Fort Knox for further study. Urine samples were collected from each subject for each day and night of bivouac. Volumes and specific gravities were measured. Quantitative analysis for creatinine and qualitative analysis for protein, acetone and sugar were made on each sample. 250 cc. of each specimen was returned to Fort Knox for further analysis.

Additional information obtained included water and food intake, daily weight changes, sweat loss during work, change in rectal temperature during sleep and during work, skin temperatures during sleep, ability to sleep and the influence of sodium amytal. Major Robert Moore of the Quartermaster R & D Branch recorded the weights and food intakes. Lt. A. Gessel, MC, conducted psychological testing on the subjects before, during, and after the bivouac exercise.

Proj. 1 71-0.1

Incomplete analysis of the data indicates that:

a. The C-2 ration was much more acceptable to the subjects at Churchill than at Fort Knox. The weight loss at Churchill was negligible compared to that found at Fort Knox. Free choice of components was allowed and the amount of C-2 ration was not limited. By the end of the bivouac period the average food intake rose to nearly 4000 Calories.

b. No obvious nocturia or diuresis was observed. A slight glycosuria and acetonuria was qualitatively demonstrable in all the men during most of the time they were in bivouac. These phenomena never appeared at Fort Knox. After the first few days of the bivouac, the urine of some subjects showed pigmentation which has not been identified.

The blood samples will be analyzed at Fort Knox for sodium, potassium and chloride. The urine samples will be analyzed for 17-ketosteroids, 11-oxycorticosteroids, nitrogen, sodium, potassium and chloride.

The basal metabolisms of six enlisted men were followed prior to and during duty at Fort Churchill. Incomplete observations have failed to indicate any significant change in basal metabolism due to duty in extreme cold. Samples of blood have been taken on these subjects and are being analyzed for blood protein bound iodine. These studies will be continued after the return of the subjects to Fort Knox. Repeated determinations of the basal metabolisms of several Eskimos are being made at Baker Lake, Canada for comparison with the basal metabolisms of troops stationed in the Arctic.

The effectiveness and value of sweat control measures under cold stress are being measured at Fort Churchill in terms of foot temperature, comfort and sweat production.

Certain items of medical equipment are being tested with emphasis on those items used for evacuation.

[illegible]

Sub-Project [illegible] 15-[illegible] Observations—Frigid and Williwaw - Dr. [illegible], Psychologist, [illegible], Capt., [illegible] and [illegible], Capt., MC.

Final report submitted [illegible] January [illegible] under title, "Observations with AGF Task Forces Frigid and Williwaw." Report is "Restricted."

[illegible] 2

[illegible]

Sub-project M.D.F.R.L. 02-3: Effects of Hypothermia on Vitamin A and Fat Metabolism in the rat - Dr. Kenneth [illegible] McConnell, Biochemist and [illegible], Capt., MC.

Several additional experiments have been completed using the newly adapted technique of feeding known amounts of Vitamin A prior to chilling. Previous findings that there is a significant change in liver, adrenal and serum Vitamin A in hypothermia have been confirmed. Attention has been focused on the possible mechanism by which these changes take place. The effects of adrenal hormones on Vitamin A levels are being investigated.

Some progress has been made in devising a suitable method for the determination of Vitamin A alcohol and Vitamin A ester.

Basic control cholesterol studies have been completed. Investigations of the effects of various cortical extracts in hypothermia are now in progress. Several interesting results concerning the role of adrenal cholesterol will be reported upon completion of further analyses of the findings.

Proj. 1, No. 3

Sub-Project [illegible]: Study of the Effects of Subnormal Temperatures on the Metabolism of Various Phosphorous Compounds in Rats - Dr. [illegible], Chief Biochemist, [illegible], 1st Lt., [illegible] and J. L. Gray.

A method for the determination of the content of adenosine triphosphate and inorganic phosphate in various tissues (muscle, liver and kidney) has been worked out.

Preliminary experiments indicate that exposure of rats to moderately low temperatures (-5° to -10°C.) up to twenty-four hours does not produce any changes in either the adenosine triphosphate or inorganic phosphate contents of muscle, liver and kidney.

Similar experiments at [illegible]°C. for a longer exposure period are being carried out.

The manometric technique of Warburg has been set up. It will be used in studying the reaction rates of various enzyme systems at different temperatures.

Proj. 1, No. 4

[illegible]

[illegible] Control of [illegible] Secretion - [illegible] Chief Biochemist and G. L. Steeples, 1st Lt., MC.

[illegible] different conditions are being studied.

[illegible] (1 cc. [illegible] of [illegible] [illegible] a lowering of the cholesterol content of the adrenal glands; indicating a stimulation of the adrenal cortex. This effect is probably mediated through the anterior pituitary. Apparently the blood sugar level not only regulates the secretion of insulin but also the secretion of the anterior pituitary. Additional experiments along this line are being carried out. The effect [illegible]

Proj. 1, No. 5

[illegible]

[illegible]: A Study of Thyroid Function at Low Environmental Temperatures with the Aid of Radioactive Iodine. [illegible], Capt., MC. and Z. S. Gierlach, 1st Lt., MC.

While it is generally believed that thyroid function is increased in cold environments, the evidence on which this view is based is far from decisive.

The most recent studies on this subject are those of Dempsey and Astwood, and of Leblond *et al.* The former authors showed by an indirect method that thyroxin release from the thyroid gland is increased in a cold environment. Leblond *et al.* used radioactive iodine to estimate the activity of the thyroid gland. They studied the uptake of radioactive iodine by the thyroid gland and its conversion to diiodotyrosin and thyroxin in rats exposed to cold (0°-2°C.) for periods up to forty days.

It was shown in experiments in which moderately large amounts of carrier iodine (5 micrograms) were injected together with the radio-iodine, that the uptake of radio-iodine by the thyroid gland and/or its conversion to thyroxin and diiodotyrosine was increased after exposure to cold for seven and twenty-six days, but was equal to the control values after 40 days' exposure. In parallel experiments in which smaller amounts of carrier iodine (0.2 micrograms) were used, a questionable decrease in uptake was obtained after one and three days' exposure to cold, and a definite decrease after seven days. A decrease in uptake was also obtained after exposure of rats to high environmental temperatures, which presumably causes a lowering of thyroid function. No longer time intervals were studied using the low-carrier dose, and no explanation offered for the discordant results.

Leblond's conclusion that "exposure of rats to cold (0°- 2°C.) for various periods of time produces a thyroid stimulation which is doubtful after one to three days, definite after seven days, maximal at 26 days, but absent after exposure for 40 days," does not seem justifiable on the basis of the data presented. Experiments to clarify the discrepancy in results in the two groups of experiments reported are indicated. The data indicating a return of thyroid function to normal after exposure for forty days appear especially in need of confirmation and extension since no other data indicate such a behaviour of the thyroid gland.

It is intended to expose rats to a temperature of 0°-2°C. for periods up to fifty days and to study their thyroid function by measuring the uptake of true tracer doses of radio-iodine (no carrier added) but also of large doses of labelled iodine (100 micrograms) throughout this period.

Proj. 1, No. 6

The first procedure will serve as a true label of the release of endogenous iodine while the second one will measure the thyroid's capacity to take up exogenous iodine.

A third procedure which is contemplated for use as a measure of thyroid function is the determination of protein-bound radioactive iodine of the plasma, as suggested by Chaikoff _et al_.

These experiments should furnish satisfactory data on the changes of thyroid function after exposure to low environmental temperatures.

PROJECT [illegible]-12-03

High Temperatures, Study of Physiological Effects of. Approved [illegible] Sept., 194[illegible] in order to study the physiology of subjects in hot environment.

Sub-Project [illegible], 03-1: Physiological Observations—[illegible] Furnace - Dr. R. W. Clarke, Physiologist and P. J. Talso, Capt., MC.

Report is in the process of final review and will be submitted in the near future.

[illegible] 1, No. 7

PROJECT 6-44-11-05

<u>Studies of Body Measurements as They Affect Physiological Efficiency</u>. Approved 31 May 1946 in order to study body measurements in relation to functional dynamics.

Sub-Project N.D.F.R.L. 05-1: Photoplanimeter - A. P. Carpenter, Chief Engineer.

Final report in press.

Prog. 1, No. 8

PROJECT 6-41-13-05

Sub-Project M.D.F.R.I. 05-2: [illegible] - L. [illegible] Carpenter, Chief Engineer.

Sub-Project M.D.F.R.I. 05-3: [illegible] - [illegible] Carpenter, Chief Engineer.

Various apparatus requisitioned to further these projects finally arrived and is now in the process of being assembled for control tests.

Proj. 1, No. 9

<u>Studies of Body Reactions and Requirements under Varied Environmental and Climatic Conditions</u>. Approved 31 May 1946 in order to study physiological reactions as altered by varied conditions.

Sub-Project M.D.F.R.L. 06-1: Renal Circulation and Excretion as Affected by Stress - Dr. R. W. Clarke, Physiologist, A. F. Crosley, Jr., Capt., MC. and P. J. Talso, Capt., MC.

Experiments on dogs are being carried out for the purpose of ascertaining the exact physiological mechanisms whose actions are responsible for the renal effects of peripheral cold. In three dogs it was found that chilling one paw did not interrupt a water diuresis. In order to verify the reliability of para-aminohippurate clearance as a measure of renal blood flow in these experiments on cold, attempts are being made to use the renal venous catheter of Selkurt.

A study is being made of the physiological significance of the "Oxford Shunt." Trueta's report on the alterations in renal circulation in response to tourniquet trauma or nerve stimulation has been studied. A number of experiments have been carried out using rats and dogs in which the renal vascular system was visualized by India ink injection after nerve stimulation, tourniquet or exposure to extreme cold. Microscopic examination of the kidneys showed, in some cases, the cortical ischemia described by Trueta. Experiments are being planned to determine if the "Oxford Shunt" is activated by any but the most extreme conditions and to determine what kind of functional tests should be used to investigate its possible importance to man.

Proj. 1, No. 10

C13

PROJECT 6-64-12-06

Sub-Project N.M.F.R.L. 06-2: Development of a Polarographic Flow Meter - E. A. Blair, Lt. Col., MSC.

Further investigation of the characteristics of the flow meter has been deferred pending delivery of apparatus.

Proj. 1, No. 11

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-3: Relation of Dietary, Metabolic and Mechanical Factors to Atherosclerotic Lesions in the Rat - Dr. D. M. Green, Chief Research Physician, H. [illegible], Capt., MC., H. [illegible] Gerlich, 1st Lt., MC., F. A. [illegible], 1st Lt., MC. and [illegible] [illegible] [illegible], 1st Lt., MC.

Methods adequate for the induction and quantitation of hypertension in the rat continue to be investigated.

Prog. 6 No. 12

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-4: The Aortic Factor in Hypertension - Dr. D. E. Gregg, Chief Research Physician and H. Schechner, Capt., MC.

Sub-Project M.D.F.R.L. 06-5: Observations on the Accuracy of the Electromagnetic Flow Meter - Dr. D. E. Gregg, Chief Research Physician and H. Schechner, Capt., MC.

Further investigation on these two projects has been deferred awaiting arrival of appropriate apparatus.

Prog. 1, No. 13

PROJECT [illegible]-12-05

Sub-Project M.D.F.R.L. 06-6: Thermal [illegible] During [illegible] - [illegible] Park, Capt., MC. and Dr. E. D. Palmes, Biochemist.

The final report in press.

[illegible] to Mc. 14

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-7: A Modification of the Infrared Gas Analyzer for Measurement of Sweat Rates Over Localized Skin Areas - Dr. W. T. Holmes, Biochemist, M. E. Albert, 1st Lt., MC. and J. J. Hart, T/4.

The infrared gas analyzer, adapted for the continuous measurement of sweat from the whole man, has been modified for use on localized skin areas. The apparatus consists of a copper cup (20 cm cross sectional area) connected to the analysis cell by lengths of gum rubber tubing. Dry O_2, at a measured rate of 6 liters per minute, is passed from one side of the analysis chamber, through the cup, to the other side. The difference in water vapor concentration in the two cells determines the magnitude of the recorded signal. The total capacity of the system is 100 cc. The clearance of the cup has been calculated to be 95% complete in 4 seconds. The apparatus has been calibrated against water vapor concentration by the introduction of a separate flow of saturated O_2 into the cup from a wet test meter. The maximum recordable frequency of change in concentration has been found to be one per second.

P. Aug 1, No. 5

PROJECT 6-64-12-06

Sub-project M.D.F.R.L. 06-3: The Effect of Certain Autonomic Drugs on Thermal Balance in Man - Dr. E. D. Palmes, Biochemist, H. [illegible], Capt., MC., R. E. Albert, 1st Lt., MC and J. J. Hart, T/4.

The data have been analyzed and the report is being written.

Proj. 1, No. 16

PROJECT 6-64-12-06

Sub-Project N.?.P.M.1. 06-?: Analysis of Cortical Components Involved in Reflex Pupillary Dilatation to Clarify the Etiology of Anisocoria Resulting from Head Trauma - W. C. Wilson, Capt., MC.

The stereotaxic apparatus developed has proved very efficient in locating cortical and subcortical centers and fiber tracts which mediate reflex pupillary dilatation through the oculomotor nerve, ciliary ganglion and short ciliary nerves. The anatomical identification of the involved structures was demonstrated by the Weil technique.

The centrifugal fibers of the excitatory gyri proreus and genualis were sectioned and the degenerated fibers could be traced by the Weil method to the caudate nucleus.

The afferent projections of the excitatory cerebral areas were too scattered to accurately localize by the stimulo-coagulation technique.

The final phase of the project, that is, the stimulation of extra cerebral hematomata is now in progress. Following ipsilateral pupillary dilatation subsequent oculomotor nucleus stimulation is contemplated to determine the state of function of the efferent arc of the reflex.

Proj. 1, No. 17

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PROJECT 6-44-13-06

Sub-Project N.M.R.I. 06-10: Development of a Photoelectric Polarimeter with Variable Electrical Field - E. L. Durrum, Capt., SC.

Further development work on this project awaits procurement and installation of Nicol prisms to replace polaroid discs and increasing of the sensitivity of the measuring bridge circuit.

Prog. 1, No. 18

PROJECT [illegible]-66-12-06

Sub-Project N.M.R.I. 06-11: Biochemical Studies on Shock - E. L. [illegible], Capt., MC., R. E. McDonald and Dr. [illegible] Jensen, Chief Biochemist.

Techniques for producing experimental traumatic shock in rats by tourniquet application have been investigated. A constant temperature and humidity box and a special apparatus for applying heavy rubber tubing tourniquets to rabbits' legs have been constructed. Pilot experiments have been carried out to ascertain optimal traumatic conditions for the study of changes in blood constituents and in certain enzyme systems of various tissues (liver and kidney) during shock.

A study of so-called "trypsin shock" in rabbits has been initiated. The protective action of heparin in preventing immediate death, probably due to the clotting properties of trypsin, has been confirmed. It is intended to determine whether or not trypsin per se will produce shock-like symptoms. This is of interest in view of the expressed idea that release of proteolytic enzymes from an injured tissue may account for the development of the symptoms of shock.

P Aug. 1, 1949 c'1

PROJECT 6-64-12-06

Sub-Project [illegible] 06-12: Spectrophotometric Studies of the Effect of Ultraviolet Radiation on the Skin - Dr. H. F. [illegible], Chief Biophysicist and Dr. A. T. Krebs.

The experimental work on this project awaits the installation of specialized equipment.

Because fluorescence microscopy will be one of the auxiliary methods used in this project, preliminary studies have been made on vital staining procedures using acridine orange and other fluorescent dyes such as auramine and pyronin.

Proj. 1, No. 20

PROJECT 6-64-12-06

Sub-Project M.D.7.R.1. 06-13: Attempts to Produce Atheroma in the Rat and Dog by Dietary Means. F. E. Herlich, 1st Lt., MC.

Atheroma and hypercholesterolemia can be easily produced in the rabbit by a variety of procedures and by a combination of cholesterol and thiouracil feedings to the dog. However, such changes have never been produced by dietary means in these experimental animals unless significant amounts of fat were present in the diet, and such changes have never been induced by any means in the rat. Recent studies by Popjak indicate that very early massive hypercholesterolemia and atheroma can be produced in the rabbit on an essentially fat free diet by administration of specially prepared cholesterol.

Studies are planned to repeat these experiments on the rabbit and to determine the effects of such a dietary regime on the production of blood vessel changes in the rat and the dog. Such experiments should contribute to the understanding of the mechanism of induction of atheromatous lesions in man.

Prog. (1 No. 2)

PROJECT 6-64-12-07

Studies of Fatigue in Relation to Military Tasks. Approved 31 May 1946 in order to study the effects of stress and strain upon the body and the physiological factors that may be altered.

There were no sub-projects under 6-64-12-07 this quarter.

Proj 1, 76.22

PROJECT 6-64-12-06

<u>Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks</u>. Approved 31 May 1946 in order to study the relationship of the soldier to his equipment, environment and task.

Sub-Project M.D.F.R.L. 06-1: Development of a Portable Apparatus for Study of Human Energy Metabolism - H. J. Spoor, Capt., MC., and P. J. Tales, Capt., MC.

Final report on this sub-project awaits the results of sub-project 06-2.

Proj. 1, 11. 2 3

Sub-Project E.G.F.R.L. 26-2: Development of Electronic Oxygen Analyzer for Adaptation to Portable Metabolic Apparatus – J. R. St. John, Capt., MC.

In order to eliminate the variables in the combustion type oxygen analyzer discussed in the preceding quarterly report, further development has included:

1. Addition of a heating element and thermostat to maintain constant temperature.

2. Incorporation of a constant head fuel system utilizing the gravity drop method.

3. Experimentation with various small air pumps which will yield a constant output with a fluctuating input. To date, one particular pump incorporating a simple archimedes screw seems most promising. Final standardization of the analyzer will proceed after development of a satisfactory pumping system.

Proj. 1, No. 24

PROJECT 6-64-12-02

Investigation of Tank Turret Controls. Approved 2 February 1948 in order to study the physiological characteristics of various controls. R. A. Blair, Lt. Col., MC and Dr. A. W. Melton, Consultant.

A study to determine the optimal physical motions required to operate power controls and firing switches of tank turrets and turret mounted guns was directed by the Surgeon General 2 February 1948. The services of Dr. Arthur W. Melton, Professor of Psychology, Ohio State University, have been obtained. A conference was held 23 March with the consultant and members of AGF Board #2. A bibliography is being assembled and detailed plans for the procurement of necessary equipment are being formulated.

Proj. 4, No. 25

M D F R L

Q U A R T E R L Y   P R O G R E S S   R E P O R T

O N

R E S E A R C H   A N D   D E V E L O P M E N T

P R O J E C T S

April 1948 to July 1948

Proj. 2.

AUTHORIZED PROJECTS

6-64-12-02 Cold, Study of the Physiological Effects of. Approved 24 Sept. 1942.

6-64-12-03 High Temperatures, Study of Physiological Effects of. Approved 24 Sept. 1942.

6-64-12-05 Study of Body Measurements as They Affect Physiological Efficiency. Approved 31 May 1946.

6-64-12-06 Study of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May, 1946.

6-64-12-07 Studies of Fatigue in Relation to Military Tasks. Approved 31 May 1946.

6-64-12-[illegible] Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks. Approved 31 May 1946.

6-64-11-02 Investigation of Tank Turret Controls. Approved 2 February, 1948.

Cold, Study of Physiological Effects of. Approved 24 Sept. 1942 in order to study the physiology of subjects in cold environment.

Sub-Project M.D.F.R.L. 02-1: Studies of Physiological Problems under Field Conditions in Extreme Cold - Dr. G. W. Molnar, Physiologist, J. R. Blair, Capt. MC., C. W. Gottschalk, Capt. MC., L. E. Osgood, Capt. MC., W. J. Zimmerman, 1st Lt., MC., W. M. Layton, 1st Lt. MC., and F. K. Smith, 1st Lt. MSC.

Seven subjects were studied under stress imposed by field conditions at Ft. Knox during the fall of 1947 and at Ft. Churchill, Canada during the winter. During April and May complementary studies were made using the cold room at Ft. Knox.

Blood and urine samples collected during the three periods of observation were frozen. Complete chemical analysis of these samples will require considerable time. Evaluation of the studies await the completion of these analyses and correlation with the other data.

Cursory examination of some of the data indicates the following tentative results:

1. The basal metabolism of the subjects showed no significant change as a consequence of cold exposure and activity.

2. Cooling rates of certain parts of the body may depend on activity of other parts.

3. Cold diuresis seems to be dependent upon posture.

4. Glycosuria noted at Churchill could not be reproduced under simulated conditions in the laboratory cold room.

5. The barrier sock reduced the amount of moisture recovered from the footgear and displaced the cooling curve.

6. The experimental casualty evacuation bag afforded adequate protection for normal men under the climatic conditions encountered.

7. Chemical heating pads were generally unsatisfactory for outdoor use.

Prog 2, No. 1

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PROJECT 6-64-12-02

Sub-Project M.D.F.R.L. 02-3: Effects of Hypothermia on Vitamin A and Fat Metabolism in the Rat - Dr. Kenneth P. McConnell, Biochemist and L. H. Tobin, Capt. MC.

A report on certain phases of this sub-project is being prepared.

Proj. 2, No. 2

Sub-Project M.D.F.R.L. 02-4: Study of the Effects of Subnormal Temperatures on the Metabolism of Various Phosphorous Compounds in Rats - Dr. H. F. Jensen, Chief Biochemist, R. N. Cagan, Capt., MC. and J. L. Gray, Biochemist.

Adenosine-triphosphate and inorganic phosphate determinations were made on liver, kidney and muscle of rats exposed to the following conditions:

1. 0°C for 1 to 4 days. No significant changes were noted.

2. -14° to -18°C for 7 to 14 hours. There was an increase in the muscle and liver values but the kidney values were normal. There was a possible glycosuria noted in these animals.

3. Starvation for 5 days. No significant changes were noted. The amino acid oxidase activity and blood sugar values were also unchanged. A decrease in adrenal cholesterol indicated a possible adrenal cortical stimulation.

4. Insulin treatment. An increase was noted in the liver values; no change in the kidney values; and a slight decrease in the muscle values.

Warburg's modified manometric technique is being used to determine changes in the amino acid oxidase systems of rat kidney and liver. A study of the effect of various ions on these enzyme systems indicates that the phosphate ion is essential. There is an optimum ion concentration for maximal enzyme activity. Concentrations of the phosphate ion above or below this optimum result in decreased and finally complete inhibition of the amino acid oxidase.

Exposing animals to starvation (5 days) or cold (5 days at 0°C) has no effect on the amino acid oxidase systems.

Tissues from insulin treated animals showed no consistent changes in these oxidase systems. The superimposed effects of succinate and glutathione on the insulin affected tissue was found to be nonspecific.

Glucose prolongs the oxidase activity but does not increase it.

Studies on the effects of adrenal cortical extracts and their protein hydrolysates on these enzyme systems are in progress.

Prog. 2, No. 3

c 12

PROJECT 6-64-12-02

Sub-Project M.D.F.R.L. 02-5: Study of the Effects of Hypothermia on the Control of Endocrine Secretion - Dr. H. F. Jensen, Chief Biochemist and G. L. Steeples, 1st Lt., MC.

The oral administration of 2 cc of a 50% aqueous solution of glucose to rats first produces a definite increase in the cholesterol content of the adrenal cortex followed by a lowering of the adrenal cortical cholesterol.

Insulin induced hypoglycemia produces a stimulation of the adrenal cortex as indicated by a pronounced fall in adrenal cholesterol.

A study of the effect of oral administration of glucose to adrenodemedullated animals is contemplated to circumvent the influence of epinephrine.

PROJECT 6-64-12-02

Sub-Project M.D.F.R.L. 02-6: A Study of Thyroid Function at Low Environmental Temperatures with the Aid of Radioactive Iodine.
H. Schachner, Capt., MC. and E. S. Gierlach, Capt., MC.

Control experiments have been run to determine the uptake of tracer doses of radioactive iodine by the thyroid glands of rats maintained on a Purina chow diet. The conversion of radioactive iodine to the protein-bound iodine of the plasma has been measured.

It was found that, under the conditions of these experiments, the conversion of injected radio-iodine to protein-bound iodine was both minimal and inconstant. This differs markedly from the results reported by Chaikoff _et al_. The uptake of radio-active iodine by the thyroid gland was only a fraction (about one-fifth) of that reported by Chaikoff. The cause of the divergent findings may be due to the possible higher iodine content of the diet used in this laboratory. This is being checked. Further control experiments using the same low iodine diet as used by Chaikoff are planned. Rats will be kept on the low iodine diet for at least three weeks before giving radioactive iodine.

Proj. 2, No. 5

PROJECT 6-64-12-03

<u>High Temperatures, Study of Physiological Effects of</u>. Approved 24 Sept. 1942 in order to study the physiology of subjects in hot environment.

Sub-Project M.D.F.R.L. 03-1: Physiological Observations—Task Force Furnace - Dr. R. W. Clarke, Physiologist and P. J. Talso, Capt., MC.

Final report submitted 1 April 1948 under title "Observations on Physiological Problems in Desert Heat - Task Force Furnace, Yuma, Arizona." Report is "Restricted".

Proj. 2, No. 6.

PROJECT 6-64-12-05

<u>Studies of Body Measurements as They Affect Physiological Efficiency.</u> Approved 31 May 1946 in order to study body measurements in relation to functional dynamics.

Sub-Project M.D.F.R.L. 05-1: Photoplanator - A. K. Carpenter, Chief Engineer.

Final report submitted 1 April 1948 under title, "Laboratory Photoplanator."

Prog. 2, no. 7

PROJECT 6-64-12-05

Sub-Project M.D.F.R.L. 05-2: X-ray Stereopanoramagraph - [illegible] Carpenter, Chief Engineer and [illegible] J. Bruce, S Sgt.

Test shots have been made and preliminary data have been collected on the essential factors of screen pitch, tube distance, etc. for making interlined stereoroentgenograms.

Prog. 2, No. 8

PROJECT 6-64-12-05

Sub-Project M.D.F.R.L. 05-3: Cineroentgenography - A. W. Carpenter, Chief Engineer and W. J. Bruce, S Sgt.

A preliminary model of a cinefluorograph has been built. Further progress awaits the delivery of special screen and film stock.

Prog. 2, No. 9

PROJECT 6-64-12-06

Studies of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946 in order to study physiological reactions as altered by varied conditions.

Sub-Project M.D.F.R.L. 06-1: Renal Circulation and Excretion as Affected by Stress - Dr. R. W. Clarke, Physiologist, A. P. Crosley, Jr., Capt. MC., P. J. Talso, Capt., MC., D. Baldwin, 1st Lt., MC. and C. E. Akers.

Studies have been made on the mode of action of various diuretics on dogs. The results will aid in the interpretation of the data on excretion of water and other substances during thermal and other stresses.

Measurements have been made on renal blood flow, glomerular filtration rate and urine flow. Sodium and potassium analyses were done on blood and urine. From these data the rates of tubular secretion or reabsorption of various plasma constituents have been calculated. The tubular reabsorption of sodium is very closely proportional to the rate of glomerular filtration. In the case of potassium no such proportionality is apparent. Further experiments are planned to study the effects of an osmotic diuretic and of the adrenal cortical hormone on the renal excretion of electrolytes.

Proj. 2, No. 10

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-2: Development of a Polarographic Flow Meter - E. A. Blair, Lt. Col., MSC.

Part of the apparatus needed for the investigation of the characteristics of the flow meter has been delivered and is being installed. On completion of the installation, the stability and sensitivity of the system using alternating currents will be investigated.

Proj. 7, No. 11

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. C6-3: Relation of Dietary, Metabolic and Mechanical Factors to Atherosclerotic Lesions in the Rat - Dr. D. E. Gregg, Chief Research Physician, H. Schachner, Capt., MC., W. E. Nerlich, 1st Lt., MC., P. A. Green, 1st Lt., MC. and E. R. Munnell, 1st Lt., MC.

A method apparently adequate for quantitation of chronic hypertension in the rat has been established. It is now being applied to the above problem as outlined in an earlier report.

Proj 2, no. 12

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-4: The Aortic Factor in Hypertension - Dr. D. E. Gregg, Chief Research Physician and H. Schachner, Capt., MC.

Sub-Project M.D.F.R.L. 06-5: Observations on the Accuracy of the Electromagnetic Flow Meter - Dr. D. E. Gregg, Chief Research Physician and H. Schachner, Capt., MC.

Further investigation on these two projects has been deferred awaiting arrival of appropriate apparatus.

Prog. 2, Tr. 16

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-6: Thermal Regulation During Fever - C. R. Park, Capt., MC. and Dr. E. D. Palmes, Biochemist.

The final report is being revised.

Proj. 2, No. 14

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-7: A Modification of the Infrared Gas Analyzer for Measurement of Sweat Rates Over Localized Skin Areas - Dr. E. D. Palmes, Biochemist, R. E. Albert, 1st Lt., MC. and J. J. Hart, T/4.

Measurements from areas of twenty square centimeters on the chest and back reveal that the evaporative rate varies approximately fourteen times per minute during moderate sweat rates. Measurements are being carried out to determine the correlation of frequency and amplitude of change in local evaporative rates to the ambient temperatures.

In addition, a micro-infrared analyzer is under construction and will be used in an attempt to measure evaporative rates from single sweat glands.

Proj. 2, No. 5

c 10

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-8: The Effect of Certain Autonomic Drugs on Thermal Balance in Man - Dr. E. D. Palmes, Biochemist, H. Schachner, Capt., MC., R. E. Albert, 1st Lt., MC. and J. J. Hart, T/4.

Final report submitted 14 April 1948 under title, "Effects of Atropine and Pilocarpine on Human Thermoregulation".

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Proj 2, No. 16

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-9: Analysis of Cortical Components Involved in Reflex Pupillary Dilatation to Clarify the Etiology of Anisocoria Resulting from Head Trauma - W. C. Wilson, Capt., MC.

The data have been analyzed and the report is being written.

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-10: Development of a Photoelectric Polarimeter with Variable Electrical Field - E. L. Durrum, Capt., MC.

Further development work on this project awaits procurement and installation of Nicol prisms to replace polaroid discs and increasing of the sensitivity of the measuring bridge circuit.

Proj. 2, No. 15

PROJECT 6-64-12-06

Sub-Project N.D.F.R.L. 06-11: Biochemical Studies on Shock - E. L. Durrum, Capt., MC., B. K. McDonald and Dr. H. Jensen, Chief Biochemist.

The adenosine-triphosphate balance has been studied in rats in which both hind limbs had been occluded by rubber band tourniquets. The increase in labile organic phosphate was demonstrated in muscle samples from the non-occluded limbs, indicating an increase in adenosine-triphosphate. The inorganic phosphate levels were within normal range.

Samples of muscle from the occluded limbs showed a decreased labile organic phosphate, indicating a decrease in adenosine-triphosphate, and an increase in inorganic phosphate. The labile organic phosphate and inorganic phosphate in the liver of these experimental animals was found to be within normal limits.

Proj 2, No. 19

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-12: Spectrophotometric Studies of the Effect of Ultraviolet Radiation on the Skin - Dr. H. F. Kuppenheim, Chief Biophysicist and Dr. A. T. Krebs.

The approach to the project continues to be theoretical due to the fact that the essential experimental equipment (spectrophotometer, spectrograph, monochromator, high-output-carbon-arc-lamp, motor-generator-set, etc.) have not yet arrived.

Proj. 2. r.c. 20

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-13: Attempts to Produce Atheroma in the Rat and Dog by Dietary Means. W. H. Herlich, 1st Lt., MC.

4

Repetition of the work of Popjak concerning the production of atheroma in rabbits on an essentially fat-free diet with specially prepared cholesterol is now in progress.

Subsequent experiments are planned to determine the effects of this dietary regime on the production of blood vessel changes in the rat and the dog.

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Proj. 2, 1st. 21

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-14: Fluorescent Microscopical Investigations on Irradiation Effects on Single Cells and Cell Groups. - Z. S. Gierlach, Capt., MC, and Dr. A. Krebs.

Vital staining techniques using acridine orange and triphenyl-tetrazolium-chloride are being used as tools in radiation studies. Preliminary investigations with onion and yeast cells, using acridine orange, indicate that the response of cells to radiation can be studied. Living cells show a bright green fluorescence while dying or dead cells change their fluorescence from green to red. By combining the staining methods with special photographic techniques (using Eastman NTA plates) it may be possible to localize the site of entry or exit of the radiation quanta.

The technique will be used to study the following questions:

1. How much radiation of the different kinds (UV, X-ray, alpha, beta and gamma rays) is necessary to kill 50% of the cells and how do the amounts differ?

2. Which part of the cell is most susceptible?

3. What are the effects of strong irradiation for short periods as compared to weak irradiations for long periods?

PROJECT 6-94-11-02

Investigation of Tank Turret Controls. Approved 2 February 1946 in order to study the physiological characteristics of various controls. E. A. Blair, Lt. Col., MSC and Dr. A. W. Melton, Consultant.

Certain experimental controls have been ordered, and contractors have been located for the construction of recording apparatus necessary for the investigation of the optimal physical motions required to operate power controls.

Proj 2, No. 23

PROJECT 6-64-12-07

Studies of Fatigue in Relation to Military Tasks. Approved 31 May 1946 in order to study the effects of stress and strain upon the body and the physiological factors that may be altered.

There were no sub-projects under 6-64-12-07 this quarter.

PROJECT 6-64-12-08

Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks. Approved 31 May 1946 in order to study the relationship of the soldier to his equipment, environment and task.

Sub-Project M.D.F.R.L. 08-1: Development of a Portable Apparatus for Study of Human Energy Metabolism - H. J. Spoor, Capt., MC., and P. J. Talso, Capt., MC.

Final report on this sub-project awaits the results of sub-project 08-2.

Prog. 2, No. 25

PROJECT 6-64-12-08

Sub-Project M.D.F.R.L. 08-2: Development of Electronic Oxygen Analyzer for Adaptation to Portable Metabolic Apparatus - J. H. St. John, Capt., MC.

Work on this sub-project has been temporarily suspended due to the return to inactive duty of the investigator. As soon as is feasible the work will be continued by another investigator.

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Prog. 2, No. 26

M D F R L

Q U A R T E R L Y   P R O G R E S S   R E P O R T

O N

R E S E A R C H   A N D   D E V E L O P M E N T

P R O J E C T S

July 19[illegible] to [illegible] 19[illegible]

Proj. 3

AUTHORIZED PROJECTS

6-64-12-02 Cold, Study of the Physiological Effects of. Approved 24 Sept. 1942.

6-64-12-03 High Temperatures, Study of Physiological Effects of. Approved 24 Sept. 1942.

6-64-12-05 Study of Body Measurements as They Affect Physiological Efficiency. Approved 31 May 1946.

6-64-12-06 Study of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946.

6-64-12-07 Studies of Fatigue in Relation to Military Tasks. Approved 31 May 1946.

6-64-12-08 Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks. Approved 31 May 1946.

6-64-11-02 Investigation of Tank Turret Controls. Approved 2 February 1942.

Cold, Study of Physiological Effects of. Approved 24 Sept. 1942 in order to study the physiology of subjects in cold environment.

Sub-Project M.D.F.R.L. 02-1: Studies of Physiological Problems under Field Conditions in Extreme Cold. - Dr. G. W. Molnar, Physiologist, J. R. Blair, Capt., M.C., L. E. Osgood, Capt., M.C., W. J. Zimmerman, Capt., M.C., and W. M. Layton, Capt., M.C.

During the summer the efforts of this group were devoted to furthering the compilation and analysis of the data collected at Ft. Churchill last winter.

The large wire thermocouples used at Churchill were tested on a copper arm in the cold room and were found to give slightly lower but always parallel values to those obtained by the screen thermocouples. It can be said that the skin temperature data from Churchill are valid.

The ratio of night urinary volume to day volume was apparently the same at both Churchill and Knox. No correlation between morning urinary volumes and morning fluid intakes can be established. For this reason the relation between morning output and total daily intake will be studied further.

The polarographic method for the analysis of urinary chloride concentration has been perfected. All of the urinary samples have been analyzed for chlorides and about one half have been analyzed for adreno-cortico-steroids. It is still too early to hazard a preliminary interpretation of the data.

Experiments with the copper arm show that clothing introduces no lag in the onset of cooling upon exposure to cold. Newton's law of cooling does not hold even for a physical object under conditions used in measuring the cooling rates of man. Tourniquet experiments to ascertain the role of the blood supply and movement on cooling have been started. Experiments also are under way to determine the role of surface composition in cooling. These investigations are necessary to give a rational background for the interpretation of the cooling experiments conducted at Churchill and at Barrow, Alaska.

Work continues on the foot sweat control problem. The following statements may be made from data collected and analyzed to date:

1. The presence of a barrier (rubber) sock decreases the recoverable sweat by about two thirds (66-71%). This appears to be about four times as effective as the anhidrotic powder used (11-17% decrease).

Proj. 3, No. 1

2. The rubber sock maintains the skin temperature of the foot at a level averaging 10°F. warmer than that of a foot similarly clothed but without the rubber sock.

3. No ill effects could be detected when the rubber sock was worn continually for two days.

Further studies will be directed toward detecting the nature (inhibition or reabsorption) of the sweat decrease produced by the presence of a barrier sock.

Considerable progress has been made in setting up a laboratory for the study of the haematological effects of hypothermia.

Prog. 3, No. 11

Sub-Project M.D.F.R.L. 02-4: Study of the Effects of Subnormal Temperatures on the Metabolism of Various Phosphorous Compounds in Rats. - Dr. H. F. Jensen, Chief Biochemist, R. N. Cagan, Capt., M.C., J. L. Gray, Biochemist, V. B. Lechleiter, Biochemist and B. K. McDonald, Technician.

In view of the fact that experimental subjects had been found to excrete glucose in their urine when subjected to severe cold (6-64-12-03-1), it was deemed of value to investigate certain enzyme systems in the kidney. These systems furnish energy directly or indirectly by way of the phosphate rich compounds. The phosphatase enzyme system is being studied.

It has been found that the kidney alkaline phosphatase of rats exposed to 0°C. for about three days was reduced to 50% of its normal value. The acid phosphatase remained within normal limits. To date no definite proof for the development of glycosuria in severe cold has been obtained. It is intended that high carbohydrate diets be fed these animals under similarly severe conditions, so that the phenomenon of glycosuria may be checked further.

In continuation of the studies on the amino acid oxidase of rat kidney and liver, the effects of amino acid administration on this enzyme system were observed. Intraperitoneal administration of a 10% amino acid solution into normal rats produced a distinct increase in the amino acid oxidase activity of the liver and kidney. On the other hand, when adrenalectomized animals were treated in this manner, there was no effect on the amino acid oxidase systems of these organs. From these observations it appears that the increased effect observed in normal animals is mediated through the adrenal cortex. Projected studies will ascertain whether injected amino acids produce a lowering of the cholesterol in the adrenal cortex. This would indicate an activation of the gland. All these experiments are controlled by blood amino acid determinations. Further studies will investigate the effect of injected amino acids on hyphophysectomized and thyroidectomized animals.

Prog. 3, No. 2

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PROJECT 6-64-12-02

Sub-Project M.D.F.R.L. 02-5: Study of the Effects of Hypothermia on the Control of Endocrine Secretion - Dr. H. F. Jensen, Chief Biochemist and C. L. Steeples, Capt. M.C.

A final report on certain phases of this project is being prepared. Hyperglycemia produced in rats by administration of glucose leads to an inhibition of the adrenal cortex while hypoglycemia produced by insulin administration leads to a stimulation of the adrenal cortex. It appears that the secretion of the adrenal cortex is under the control of the blood sugar level. This controlling effect of the blood sugar level apparently is mediated through the adrenal medulla.

Investigations of the effects of various cortical extracts upon the cholesterol content of the adrenals in rats in the cold initiated by sub-project 6-64-12-02-3 will be further studied. On the basis of the findings reported above, the effect of glucose administration on the adrenals of rats exposed to hypothermia will be studied.

Prog, 3, Mo, 9

Sub-Project M.D.F.R.L. 02-6: A Study of Thyroid Function at Low Environmental Temperatures with the Aid of Radioactive Iodine.
H. G. Schachner, Capt., M.C., Z. S. Gierlach, Capt., M.C. and A. Krebs, Biophysicist.

The proposed experiment has been modified to include measurements of radioactive iodine in the thyroxine, diiodotyrosine and inorganic fractions of the thyroid instead of determining only total uptake of I^{131}. This fractionation procedure has been set up and preliminary check experiments have been run.

Data recently reported by Wolff and Chaikoff* on the inhibition of iodide uptake and conversion, in rat thyroids, by large doses of inorganic iodide made a further modification of the proposed experiment advisable. Only tracer doses of radioactive iodide will be used in this study.

While waiting for the low iodine diet Wolff and Chaikoff's inhibition experiments on rats, which were presumably on a high iodine diet, were repeated. The results obtained were markedly different from those reported from California. No inhibition of iodide uptake or conversion could be demonstrated even with doses of iodide exceeding those used in California. The cause for this divergence will be investigated further.

* J. Biol. Chem. 172, 855 (1948)
Ibid 174, 555 (1948)
Endocrinology 42, 468 (1948)

Proj. 3, No. 4

c) 1

High Temperatures, Study of Physiological Effects of. Approved 24 Sept. 1942 in order to study the physiology of subjects in hot environment.

There were no sub-projects under 6-64-12-03 this quarter.

Proj. 3, No. 5

Studies of Body Measurements as They Affect Physiological Efficiency. Approved 31 May 1946 in order to study body measurements in relation to functional dynamics.

Sub-Project M.D.F.R.L. 05-2: X-ray Stereopanoramograph. - A. W. Carpenter, Chief Technologist.

Test shots have been made and preliminary data have been collected on the essential factors of screen pitch, tube distance, etc. for making interlined stereoroentgenograms. Several interlined parallax stereograms of progressively improved quality have been prepared.

Prog. 3, no 6

Sub-Project M.D.F.R.L. 05-3: Cineroentgenography - A. W. Carpenter, Chief Technologist.

A preliminary model of a cinefluorograph has been built. Further progress awaits the delivery of special screen and film stock.

Prog. 3, No. 7

Studies of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946 in order to study physiological reactions as altered by varied conditions.

Sub-Project M.D.F.R.L. 06-1: Renal Circulation and Excretion as Affected by Stress - Dr. R. W. Clarke, Physiologist, D. Baldwin, 1st Lt., M.C. and Dr. E. M. Kahana, Physiologist.

Studies have continued on the action of typical diuretics on renal functions of dogs. The four substances studied were mersalyl (Salyrgan, plain) aminophyllin, hypertonic saline and hypertonic mannitol solutions. The tubular reabsorption of sodium and potassium was measured.

The data are being compiled and will be incorporated in a formal report. Of the substances studied hypertonic saline is most active in raising glomerular filtration, aminophyllin in depressing tubular reabsorption of potassium, and mersalyl in depressing the tubular readsorption of sodium. Mannitol caused a slight fall in filtration, a considerable depression of sodium reabsorption and a greater depression of potassium reabsorption.

A phase of this work was presented before the American Physiological Society at Minneapolis 16 Sept. 1948. The title of the paper was "The influence of various diuretic substances on the renal excretion of electrolytes in the dog."

Studies are being made of the part played by adrenal cortical and posterior pituitary hormones on the tubular transfers of water and electrolytes, especially sodium, potassium, and chloride in the dog.

Studies are being made of the processes of acidification of the urine, especially to determine the reasons for the apparent delay in acid excretion.

Proj. 3, no. 8

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-2: Development of a Polarographic Flow Meter - S. A. Blair, Lt. Col., M.S.C.

Part of the apparatus needed for the investigation of the characteristics of the flow meter has been delivered and is being installed. On completion of the installation, the stability and sensitivity of the system using alternating currents will be investigated.

Proj. 3, no. 9

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-3: Relation of Dietary, Metabolic and Mechanical Factors to Atherosclerotic Lesions in the Rat. - Dr. D. E. Gregg, Chief Research Physician, W. H. Merlich, Capt., M.C., P. A. Green, Capt., M.C. and E. H. Munnell, Capt., M.C.

Procedures apparently adequate for the creation of chronic hypertension are now being standardized. This will make available a satisfactory method for quantitation of the hypertension. These procedures and methods are being applied to the above problem.

Proj. 3, No. 10

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-6: Thermal Regulation During Fever. - C. R. Park, Capt., M.C. and Dr. E. D. Palmes, Biochemist.

The final report is being prepared.

Proj. 3, Item 11

Sub-Project M.D.F.R.L. 06-7: A Modification of the Infra-red Gas Analyzer for Measurement of Sweat Rates Over Localized Skin Areas - R. E. Albert, Capt., M.C. and R. D. Kuhlmann, S.F.C.

Experiments to determine the characteristics of local sweat rates are being continued. Size frequency distribution analysis of sweat rates, and frequency of change of sweat rates are being studied. The construction of a micro-infra-red analyzer has been interrupted pending arrival of certain materials.

Prog. 3, Ma, '42

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-9: Analysis of Cortical Components Involved in Reflex Pupillary Dilatation to Clarify the Etiology of Anisocoria Resulting from Head Trauma - W. C. Wilson, Capt., M.C.

Final report submitted 15 July 1948 under title "An Analysis of Cerebral Control of Reflex Pupillary Dilatation in the Cat."

Proj. 3. No. 13

Sub-Project M.D.F.R.L. 06-10: Development of a Photoelectric Polarimeter with Variable Electrical Field - E. L. Durrum, Capt., M.C.

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No work has been done on the photoelectric polarimeter proper during this quarter. However, related work concerning the development of a scanning system for measuring refractive index gradients according to the Schlieren method have been investigated. A new principle has been employed which permits eliminating the large expensive lenses utilized in the conventional Schlieren method as employed for example in a Tiselius apparatus. The new principle comprises mechanically scanning a conventional Tiselius cell in the following manner: A point source provided by a two watt zirconium arc lamp provided with suitable slits is moved mechanically vertically upward, the narrow beam traversing at successive intervals, regions of refractive index gradient. On the opposite side of the cell, a photographic plate synchronized with the vertical beam, moves in a lateral direction past a vertical slit. Under these circumstances, it has been found that the narrow band of light emanating from the point source and slit system is deflected as it passes through the region of refractive index gradient concentration. These deflections are recorded on the photographic plate as a curve, the shape of which depends upon the concentration gradient. With the relatively crude apparatus so far available, a surprisingly sharp picture of a single gradient between a concentrated sodium chloride-water boundary has been achieved without any Schlieren or camera lenses being used. It is hoped, in the future, to scan a protein solution with this apparatus and compare the pattern obtained with that obtained by a conventional Tiselius apparatus. This comparison should establish the desirability of carrying this aspect of the investigation farther, but must await installation of the Tiselius equipment now on order.

Another apparatus based upon this principle is under construction. Here the photographic plate has been replaced with a photoelectric cell. In this modification an arm carrying both the point source and the photoelectric cell on opposite sides of the Tiselius cell will simultaneously vertically scan concentration gradients. The photocell is provided with a V-slit so that any deflection of the beam will cause a change in the total quantity of light falling upon the photocell. The output of this photocell is to be amplified and fed to an electric pen recorder. It is hoped that in this manner, it will be possible to obtain the equivalent of an ordinary Tiselius diagram.

In both the preceding procedures, perhaps the most important possibility is that of scanning very long electrophoresis or diffusion cells since the cell length is not limited to the relatively short values dictated by the small diameters available in practical lenses.

Proj. 3, No. 14

Another advantage to these processes is the relatively small size of the apparatus with considerable simplification and, therefore, presumably decreased cost. The second type of apparatus described, possibly would lend itself to adaptation of semi-automatic design in which many simultaneous electrophoretic determinations could be carried out.

Proj. 3, No ~~15~~ 14

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-11: Biochemical Studies on Shock. - E. L. Durrum, Capt., M.C., Dr. H. Jensen, Chief Biochemist and M. L. Hamolsky, 1st. Lt., M.C.

During the last quarter a series of experiments have been carried out on mice, using a slight modification of the technique of Rosenthal*. In these experiments, mice weighing about 25 grams are subjected to double rubber band tourniquets on the hind limbs. The tourniquets are left on 2½ hours and then removed. Half of the animals are given intraperitoneal injections of 1½ cc. normal saline solution, the other half being used as controls. The treated animals are given another 3/4 cc. of saline intraperitoneally three hours later and a subsequent 3/4 cc. of saline intraperitoneally six hours after the removal of the tourniquets. During the period of application of tourniquets and the succeeding six hours, the animals are kept in an incubator at 29 C. Under these conditions, mortality figures for the treated animals as compared with the untreated animals are of the same order as those given by Rosenthal. These experiments have been carried out in an effort to standardize a technique for use as a base line in evaluating contemplated experiments in shock and of themselves clearly point out the importance of electrolyte balance in animals subjected to this form of trauma. (64% of the untreated animals died as compared to only 2.3% of the treated animals.)

A systematic study of the changes of electrolytes, Na^+, K^+, Mg^{++} and Cl^-, in various organs (kidney and liver) in shocked rats is contemplated. Changes observed will be correlated with possible changes of certain enzymic activities in these organs. Means to re-establish a normal electrolyte balance in shocked animals will be studied.

* Pub. Health Reports 58, 1429 (1943)

Proj. 3, no. 15

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-12: Spectrophotometric Studies of the Effect of Ultraviolet Radiation on the Skin - Dr. H. F. Kuppenheim, Chief Biophysicist, Dr. K. Schocken, Biophysicist, and Dr. A. T. Krebs, Biophysicist.

Most of the specialized, essential equipment has been installed and is being calibrated.

Proj. 3, No. 16

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-13: Attempts to Produce Atheroma in the Rat and Dog by Dietary Means. W. E. Gerlich, Capt., M.C.

Experiments, repeating the work of Popjak* in producing atheroma in rabbits on an essentially fat-free diet with specially prepared cholesterol, continue.

Further experiments, planned to determine the effects of this dietary regime on the production of blood vessel changes in the rat and the dog, are now in progress.

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* Popjak, G. Biochemical Journal 40, 608, 1946.

Proj. 3, no. 17

Sub-Project M.D.F.R.L. 06-14: Vital Staining of Tissues and Cells as a Tool for Studying Radiation Damage. - Dr. A. T. Krebs, Biophysicist and Z. S. Gierlach, Capt., M.C.

In continuing the work with fluorochromes the vital stain 2,3,5 thyphenyl tetrazolium chloride has been investigated. This substance can be reduced easily by chemical and photochemical means to its red, water-insoluble formozon (see Straus*).

Ultraviolet light of wave lengths shorter than 3650 Å and alpha rays from plutonium preparations will reduce this compound. This finding opens up possibilities of utilizing this property in the field of actinometry in climatology and as a practical dosimeter in physical medicine. It also may contribute to current theories of the effects of radiation on aqueous solutions (see Weiss**). Since water is a major constituent of biological material this substance can serve as a useful tool in studying radiation damage.

A formal report on certain phases of this work is being prepared.

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* F. H. Straus, *et al.* Science 108, 113, 1948
** J. Weiss, Trans. Far. Soc. 43, 314, 1947

Proj. 3, no. 18

Sub-Project M.D.F.R.L. 06-15: Study of the Central Nervous Control of Heat Regulation under Environmental Stresses. - Dr. A. D. Keller, Chief Physiologist and J. R. Lynch, Physiologist.

The immediate approach to the problem will be an investigation of the heat regulating ability of dogs having destructive lesions in the neural portion of the pons. Special emphasis will be placed on the effects of sectioning the pyramidal bundles. This approach should elucidate the relative importance of the nerve fibers in the medullary pyramidals subserving heat maintenance functions to over-all heat regulating ability.

It has been shown by the chief investigator (Amer. J. Physiol., in press) that the entire brain stem can be transected except for the medullary pyramidals without eliminating the dog's ability to combat cold environment. This demonstrates that nerve fibers subserving heat maintenance functions descend through the pons in the pyramidal bundles. The question arises as to whether all the nerve fibers subserving heat maintenance functions are localized to the pyramidal bundles, or whether some such fibers course in other regions of the cross sectional area of the pons? This question can be resolved in assaying the heat regulating abilities of animals after placing lesions which completely sever the pyramidal bundles. On the basis of previous literature concerning the destruction of these bundles, with other objectives in mind experimental or otherwise, it seems essentially certain that heat maintenance fibers will be found to transverse the pons other than in the pyramidal bundles.

Proj. 3 yr. 19

PROJECT 6-64-12-07

<u>Studies of Fatigue in Relation to Military Tasks</u>. Approved 31 May 1946 in order to study the effects of stress and strain upon the body and the physiological factors that may be altered.

There were no sub-projects under 6-64-12-07 this quarter.

Proj. 3, No. 20

PROJECT 6-64-12-08

Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks. Approved 31 May 1946 in order to study the relationship of the soldier to his equipment, environment and task.

Sub-Project M.D.F.R.L. 08-1: Development of a Portable Apparatus for Study of Human Energy Metabolism - H. J. Spoor, Capt., M.C., and P. J. Talso, Capt., M.C.

Further work on this sub-project awaits the finding of a suitable fuel for the oxygen analyzer and the construction of a working model.

Proj. 3, no. 21

Investigation of Tank Turret Controls. Approved 2 February 1948 in order to study the physiological characteristics of various controls. E. A. Blair, Lt. Col., M.S.C. and Psychology Consultants.

Certain experimental controls have been ordered, and contractors have been located for the construction of recording apparatus necessary for the investigation of the optimal physical motions required to operate power controls.

A survey of the problem including recommendations has been compiled by Dr. R. S. Daniels, Psychology Consultant.

Actual work on the project probably will await the assignment of permanent psychology personnel.

Proj, 3, No. 22

M D F R L

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P R O J E C T S

October 1948 to January 1949

Prog. 4

[illegible]

[illegible]	Cold, Study of the Physiological Effects of. Approved 24 Sept. 1942.
[illegible]	High Temperatures, Study of Physiological Effects of. Approved 24 Sept. 1942.
6-64-12-05	Study of Body Measurements as They Affect Physiological Efficiency. Approved 31 May 1946.
6-64-12-06	Study of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946.
6-64-12-07	Studies of Fatigue in Relation to Military Tasks. Approved 31 May 1946.
6-64-12-08	Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks. Approved 31 May 1946.
[illegible]-11-02	Investigation of Tank Turret Controls. Approved 2 February 194[illegible].

<u>Cold, Study of Physiological Effects of.</u> Approved 24 Sept. 1942 in order to study the physiology of subjects in cold environment.

Sub-Project M.D.F.R.L. 02-1: Studies of Physiological Problems under Field Conditions in Extreme Cold.—Dr. G. W. Molnar, Physiologist, J. H. Blair, Capt., M.C., L. E. Osgood, Capt., M.C., C. J. Zimmerman, Capt., M.C., and W. M. Layton, Capt., M.C.

It is anticipated that the final analyses of the urines for 11-oxycortico-steroids and 17-ketosteroids will be complete by 1 February 1949. General trends, if present, are still not obvious because the analyses were not performed in a consecutive series.

All of the samples of urine have been analyzed for chloride. The mean daily output at Churchill was not significantly different from that at Ft. Knox. In general, the output was remarkably parallel to the intake, as calculated from the salt content of the ingested components of the C-2 ration. There were exceptions, however, especially during the latter part of the bivouac exercise at Ft. Knox where the urinary output showed a progressive increase while the intake was progressively decreasing. The explanation of this anomaly will have to await the analyses for sodium and potassium (to be completed in the near future).

The skin temperature records obtained under standard conditions before and after going to Churchill have been plotted. Interpretation of the results is difficult. For example, when a tourniquet is placed on one thigh, that leg, with blood flow occluded, apparently does not cool faster, if as fast, as the leg with active blood flow. The roles of vasoconstriction and blood flow in the maintenance of skin temperature, therefore, are not clear. Further experimentation will be necessary before cooling tests for field work can have much significance.

However, the Churchill experiments, both as to subjective feeling and skin cooling, suggest acclimatization changes. There seems to be no particular correlation between endurance and acclimatization since the man with the least endurance showed as much improvement in thermal well being as did the other men. These tests were not designed to elucidate thermal acclimatization. They were merely meant to be an index of acclimatization if it did occur.

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 02-4: Study of the Effects of Subnormal Temperatures on the Metabolism of Various Phosphorous Compounds in Rats.--Dr. H. F. Jensen, Chief Biochemist, R. H. Cagan, Capt., M.C., J. L. Gray, Biochemist, V. C. Lochleiter, Biochemist and W. K. McDonald, Technician.

In continuation of the studies on the amino acid oxidase of rat kidney and liver, the effects of amino acid administration on this enzyme system were observed. Intraperitoneal administration of a 10% amino acid solution into normal rats produced a distinct increase in the amino acid oxidase activity of the liver and kidney. The increase of amino acid oxidase activity in either organ depended upon the time elapsed between the injection and the killing of the animals. The increase was first noticed in the kidney.

Adrenalectomized animals did not show this increase in the liver. Kidney studies in these animals showed intensified increase in the enzyme activity.

Hypophysectomized animals showed the same results as adrenalectomized animals with the additional information that the total oxidase activity was increased. Blood amino acid and urea determinations were used as control measures to determine the biochemical status of the animals.

Proj. 4, No. 2

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PROJECT 6-64-12-02

Sub-Project M.D.F.R.L. 02-5: Study of the Effects of Hypothermia on the Control of Endocrine Secretion — Dr. H. F. Jensen, Chief Biochemist and G. L. Steeples, Capt. M.C.

A final report on one phase of this project is being prepared.

Investigations of the effects of adrenocortical extracts upon the cholesterol content of the adrenals in rats exposed to cold have been completed. It was found that administration of adrenocortical extracts caused a definite decrease in the lowering of the adrenal cholesterol caused by cold exposure.

Proj. 4. No 3,

PROJECT 6-64-12-02

Sub-Project M.D.F.R.L. 02-6: A Study of Thyroid Function at Low Environmental Temperatures with the Aid of Radioactive Iodine.—H. G. Schachner, Capt., M.C., E. S. Gierlach, Capt., M.C. and A. Krebs, Biophysicist.

The amounts of inorganic I^{131} taken up and the per cent converted into organic fractions have been determined using rats exposed to moderate cold (40°F). Time intervals up to and including 26 days have been completed. Time interval up to 60 days are to be run.

The fractionation is carried out only into inorganic and organic fractions since this simple procedure shows significant difference. It has been found that reproducible results can be obtained using a stock diet.

Proj. 4, No. 4

PROJECT 6-64-12-03

<u>High Temperatures, Study of Physiological Effects of</u>. Approved 24 Sept. 1942 in order to study the physiology of subjects in hot environment.

There were no sub-projects under 6-64-12-03 this quarter.

Prog. 4, 71-5

PROJECT 6-64-12-05

Studies of Body Measurements as They Affect Physiological Efficiency. Approved 31 May 1946 in order to study body measurements in relation to functional dynamics.

Sub-Project [illegible] 05-2: X-ray Stereopanoramograph.—[illegible] Carpenter, Chief Technologist.

Test shots have been made and preliminary data have been collected on the essential factors of screen pitch, tube distance, etc., for making interlined stereoroentgenograms. Several interlined parallax stereograms of progressively improved quality have been prepared.

Prog. [illegible]

PROJECT 6-64-12-05

Sub-Project M.D.F.R.L. 05-3: Cineroentgenography.—A. W. Carpenter, Chief Technologist.

Equipment has been developed to permit the taking of acceptable x-ray motion pictures on 16 mm film at speeds up to 24 frames per second and with tolerance doses of radiation permitting operation with human subjects for 6 to 12 second cycles. With the addition of radiation occluding shutters, now in construction, these operation cycles will be doubled. It is felt that 20 to 30 second cycles would serve all reasonable needs for research with human subjects until such a time as the Westinghouse electron image type of X-ray scanning tubes become available. These new devices will result in about a 400 fold increase in time or speed.

Proj. V, No. 2

Studies of Body Reactions and Requirements under Varied Environmental and Climatic Conditions. Approved 31 May 1946 in order to study physiological reactions as altered by varied conditions.

Sub-Project M.D.F.R.L. 06-1: Renal Circulation and Excretion as Affected by Stress.—Dr. N. E. Clarke, Physiologist, D. Baldwin, 1st Lt., M.C. and Dr. E. M. Kahana, Physiologist.

Experiments have been carried out on dogs to clarify some of the major factors in the regulation of the renal excretion of sodium and potassium. The effects of varied concentrations of serum sodium and potassium upon filtration rates and tubular reabsorption were studied. The most significant finding is that the renal tubular transfers of potassium appear to be related to, (1) the serum sodium concentration and (2) the total body store of potassium.

A report will appear soon on the influence of various diuretic substances on the renal excretion of electrolytes.

Proj. 4. No. 8

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-2: Development of a Polarographic Flow Meter.—E. A. Blair, Lt. Col., M.S.C.

Part of the apparatus needed for the investigation of the characteristics of the flow meter has been delivered and is being installed. On completion of the installation, the stability and sensitivity of the system using alternating currents will be investigated.

Prog. 4, No. 9,

PROJECT 6-64-12-06

Sub-project M.D.F.R.L. 06-3: Relation of Dietary, Metabolic and Mechanical Factors to Atherosclerotic Lesions in the Rat.— Dr. D. E. Gregg, Chief Research Physician, [illegible] [illegible] Gerlich, Capt., M.C., P. [illegible] Green, Capt., [illegible], [illegible] D. Burnell, Capt., M.C. and [illegible] [illegible] Sealy, 1st Lt, M.C.

A method adequate for the quantitation of hyperpiesis in the rat has been established. Methods continue to be devised and tried for the induction of hypertension.

Proj. 4, No. 10

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-6: Thermal Regulation During Fever.—C. R. Park, Capt., M.C. and Dr. E. D. Palmes, Biochemist.

Final report submitted 1 October 194[illegible] under title, "The Regulation of Body Temperature During Fever."

Abstract of report: Changes in body temperature are due almost entirely to autonomic regulation of peripheral blood flow, sweat secretion, and muscular activity. Peripheral blood flow, by altering the skin temperature, is a control of heat exchange by convection and radiation; sweating is a control of evaporative cooling; and muscular activity, in the form of shaking chills, controls metabolic heat production. Sweating and muscular activity secondarily cause changes in convection and radiation. These changes are opposed to the primary thermal effects of sweat secretion and chills but are smaller in magnitude.

The pattern of temperature regulation in fever is governed by the thermal nature of the environment and the strength of the pyrogenic stimulus. Whenever possible, temperature changes are brought about by altering the rate of heat loss from the body rather than by changing the rate of heat production.

To raise the body temperature, heat production can be increased, heat loss restricted, or both changes can be induced.

Peripheral blood flow and sweating must be restricted in order to maintain a normal body temperature in a cool environment. Since heat loss cannot be reduced appreciably a febrile rise can be accomplished only by increasing heat production, i.e., by muscular activity, and the degree of fever will be proportional to the severity of the chill. When the environment is warm (above 30°C.), fever can be produced by decreasing heat loss, i.e., restriction of peripheral blood flow and sweat secretion. Unless the environment is very hot, however, only gradual temperature rises can be effected. If the pyrogenic stimulus demands a sharp rise in temperature, a chill is superimposed on restricted heat loss even in very hot environments.

The lysis of fever may be a passive or an active process. Passive cooling occurs when there is no increase in peripheral blood flow or sweat secretion. The skin temperature is elevated at the height of fever and the greater loss of heat by convection and radiation exceeds heat production. Passive cooling can occur only in a cool environment after fever induced by a chill, or after a fall in environmental temperature. When peripheral blood flow and/or sweating increases, as is usually the case, cooling is active. Active cooling is necessary in hot environments, or to produce rapid defervescence in cooler surroundings.

Proj. 4, No. 11.

c-1

PROJECT 6-64-12-06

Sub-Project N.M.R.I. 66-7: A Modification of the Infra-red Gas Analyzer for Measurement of Sweat Rates Over Localized Skin Areas.--R. E. Albert, Capt., M.C.

A report is being prepared on the first phase of the project. Further work will deal with the physiological mechanisms underlying the observed phenomenon of a rhythmically fluctuant sweat rate.

Proj. 4, No. 12

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-10: Development of a Photoelectric Polarimeter with Variable Electrical Field.—E. L. Durrum, Capt., M.C.

Further work on this project awaits the installation of the Tiselius apparatus in order to check the method.

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-11: Biochemical Studies on Shock.—
Dr. H. Jensen, Chief Biochemist and M. L. Hamolsky, 1st. Lt., M.C.

A method has been standardized for the production of a shock-like state in rats by the application of tourniquets to the hind limbs. Within 24 hours a mortality of 90% of 80 rats was produced. Following intraperitoneal injections of isotonic saline (10% of body weight), beginning at time of removal of the tourniquets, lowered the mortality to 8.7% in 24 hours in 23 animals and to 30.4% in 48 hours in 23 animals. Intraperitoneal injection of isotonic glucose solution failed to lower the mortality rate.

Several groups of animals have been subjected for various time intervals to repeated sublethal occlusions in an attempt to study the possibility of "adaptation". Necessary controls relative to time of occlusion are being established.

Preliminary studies of the effects of magnesium and potassium salts are being carried out.

Proj. 4, 7/6/44

PROJECT 6-64-12-06

Sub-Project M.D.F.N.I. 06-12: Spectrophotometric Studies of the Effect of Ultraviolet Radiation on the Skin.—Dr. H. F. Oppenheim, Chief Biophysicist, Dr. K. Schocken, Biophysicist, and Mr. D. J. Rowe, Biophysicist.

Spectrophotometric measurements on normal skin of white and colored subjects have been made. Photochemical experiments, combined with optical measurements, on amino acids are being set up to study the process of pigmentation.

Proj. 6, 72 . 25

PROJECT 6-64-12-06

Sub-Project M.D.F.R.L. 06-13: Attempts to Produce Atheroma in the Rat and Dog by Dietary Means. [illegible]. E. Merlion, Capt., M.C.

Experiments designed to determine the effects of specially prepared cholesterol on the production of blood vessel changes in the rat and the dog continue.

Proj, 4, No, 16

PROJECT 6-64-12-06

Sub-Project A.M.R.L. 06-1A: Vital Staining of Tissues and Cells as a Tool for Studying Radiation Damage.--Dr. A. T. Krebs, Biophysicist and Z. S. Gierlach, Capt., M.C.

A report (6-64-12-06-(16)) on one phase of this work was submitted 1 December 1948 under the title, "Some Preliminary Observations on the Effects of Ultraviolet Light, Alpha Rays and X-rays on 2,3,5-Triphenyltetrazolium Chloride Solutions."

Abstract of the report: Ultraviolet light (3650A to 2536A) reduces 2,3,5-triphenyltetrazolium chloride in solution to its red formazan. The amount of reduction depends upon the intensity of the light source and/or the time of exposure. The rate of formation of the red formazan increases with an increase in concentration of the salt solution. The reduction is influenced by pH and temperature. Alpha radiation and X radiation also reduce the salt to its red formazan.

It is believed that this study is an experimental contribution to the theory of Weiss on radiochemistry of aqueous solutions.

The importance of the application of this phenomenon in ultraviolet dosimetry, in medical therapy and in climatological problems is obvious.

Proj. 4, No. 17

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PROJECT 6-64-12-06

Sub-Project N.M.F.R.L. 06-15: Study of the Central Nervous Control of Heat Regulation under Environmental Stresses.—Dr. A. D. Keller, Chief Physiologist and J. R. Lynch, Physiologist.

Satisfactory progress has been made in obtaining equipment and materials essential to the activation of this project.

Some preliminary studies will soon be made on the effects of surgical removal of various parts of the cerebellum in dogs.

Proj, 4. no. 18

PROJECT 6-64-12-07

Studies of Fatigue in Relation to Military Tasks. Approved 31 May 1946 in order to study the effects of stress and strain upon the body and the physiological factors that may be altered.

There were no subprojects under 6-64-12-07 this quarter.

Proj. 4, no. 19

PROJECT 6-64-12-08

Studies of Physiological and Psychological Problems of Military Personnel in Relation to Equipment, Environment and Military Tasks. Approved 31 May 1946 in order to study the relationship of the soldier to his equipment, environment and task.

Sub-Project M.D.F.R.L. 08-1: Development of a Portable Apparatus for Study of Human Energy Metabolism.—H. J. Spoor, Capt., M.C.

Further work on this sub-project awaits the finding of a suitable fuel for the oxygen analyzer and the construction of a working model.

Proj. 4, No. 20

PROJECT 6-64-11-02

Investigation of Tank Turret Controls. Approved 2 February 1948 in order to study the physiological characteristics of various controls. E. A. Blair, Lt. Col., M.S.C. and Psychology Consultants.

Authorization for a permanent psychophysiological section at MDFRL has been obtained. Personnel are being selected by the Office of the Surgeon General. Work on this project is being deferred until full time psychologists are available.

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Proj. 4 No 21

Farley